# The American Biology Teacher

DECEMBER, 1959 VOLUME 21, No. 8

Oceanography
Gradient Agar Plates
Advanced Placement Program
Plant Physiology Exercises
Index to Volume 21

## TABLE OF CONTENTS



### Cover Picture

Dr. Walter H. Munk, geophysicist, is one of the several faculty members of the University of California's Scripps Institution of Oceanography who have become proficient in the use of self-contained underwater breathing apparatus. This photograph, taken in the South Seas on Capricorn Expedition, 1952-53, shows him hovering over a giant coral that is growing in water 120 feet deep. The photograph was taken by John B. MacFall, Scripps photographer.


### THE AMERICAN BIOLOGY TEACHER

Publication of the National Association of Biology Teachers.

Issued monthly during the school year from October to May. Second class postage paid at Danville, Illinois.

**Publication Office—Interstate Press, 19 N. Jackson St., Danville, Ill.**

Editor—PAUL KLINGE, Coordinator for School Science, Indiana University, Bloomington, Indiana.

The Indiana University address will be the official editorial office.

Managing Editor—MURIEL BEUSCHLEIN, 6431 S. Richmond, Chicago 29, Ill.

Subscriptions, renewals, and notices of change of address should be sent to the Secretary-Treasurer, PAUL WEBSTER, Bryan City Schools, Bryan, Ohio. Correspondence concerning advertising should be sent to the Managing Editor.

Annual membership, including subscription, $6.00; subscription to Journal, $6.00; individual copies $.80; outside United States, $6.75; student membership, $2.00.




### MEMBERSHIP APPLICATION

### NATIONAL ASSOCIATION OF BIOLOGY TEACHERS

Name ______________________
(PLEASE PRINT)

Address ______________________

______________________

Dues: $6.00 a year, including subscription to

THE AMERICAN BIOLOGY TEACHER
For one year (8 issues)

THE AIBS BULLETIN
For one year (5 issues)

Send application to:

**Paul Webster, Secretary-Treasurer**
**Bryan City Schools, Bryan, Ohio**

# Dear Student: Are You Interested in Oceanography?

CHARLES D. WISE
*Institute of Marine Science, University of Texas, Port Aransas, Texas*

The oceans, taken together, cover over seventy percent of the earth's surface, or approximately one hundred and forty million square miles. The volume of these waters is fourteen times all the land above sea level. In spite of their vastness, in the past there has been little understanding and too little organized study of the oceans. Recently, however, more and more people are becoming interested in the seas. Many persons believe the oceans hold the solution to problems of food, water, and other resources for the world's increasing population. Research scientists are finding stimulating research problems in all areas of marine science, and our nation is developing an increasing awareness of the seas.

The National Academy of Sciences Committee on Oceanography has recently urged the Federal Government to double its basic research in oceanography in the next decade and recommends the expenditure during that period of 65 million dollars per year mostly for seventy new research ships. The surprising showing by competitive nations during the International Geophysical Year has given a sense of urgency to the subject, for the oceans are important to our economic and military strength.

Young people desiring careers in marine science can look forward to years of challenging and rewarding work in their chosen field. For sources of jobs in the future, marine scientists can look to some 180 aquatic research laboratories and 49 state organizations with one or more laboratories each. Graduates, adequately prepared in marine science, are much in demand by industrial concerns such as oil companies, fisheries, and chemical companies. Also, there shall continue to be a growing demand for marine scientists to fill university and college teaching positions in the two thousand or so universities and colleges of the country.

Good planning and sufficient preparation are the keys to success in those future years. In high school, students should get a solid background of mathematics, science, English, and foreign languages. Math should receive most careful attention, and plane geometry, trigonometry and two years of algebra are recommended. Good English is required for scientific publications, and a knowledge of composition, sentence structure, and other mechanics of construction is as important as a good vocabulary. All courses in science, such as chemistry, biology, and physics, are helpful. Foreign languages are essential, with German and French most often required by graduate schools for science majors. Russian has recently become of importance to scientific workers. College students who plan to enter marine science should have a strong major in one of the sciences including botany, zoology, bacteriology, chemistry, geology, physics, or meteorology, with a minor in a supporting scientific field. It is highly desirable that the major and minor be supported, at least, by the basic courses of the other sciences. The undergraduate student has a wide choice of fully accredited colleges or universities with good reputations for the sciences. For graduate work, the beginning marine scientist will probably want to get a more specialized advanced training in a college or university with a strong department of limnology or oceanography, as for example: The University of Texas, Texas A & M College, Duke University, Scripps Institution of California, The University of Wisconsin, The University of Michigan, The University of Washington, The University of Miami, The University of Oklahoma, Cornell University, Harvard University, and Yale University.

Students in high school or junior high school should request that their science teachers include units on marine science. Field trips to museums, marine laboratories, aquaria, and the seashore should supplement regular course work. Leisure time activities such as reading, nature study, and observing, can do much to help develop broad concepts and appreciations pertaining to the seas. Some recommended aquaria and museums for the prospective marine scientist to visit are:

- American Museum of Natural History, New York City
- Chicago Natural History Museum, Chicago, Illinois
- Marine Studios, Marineland, Florida
- Municipal Aquarium, Key West, Florida
- Shedd Aquarium, Chicago, Illinois
- Steinhart Aquarium, San Francisco, California
- Beal-Maltbie Shell Museum, Rollins College, Winter Park, Florida

Some marine stations which one may visit are:

- Institute of Marine Science, Port Aransas, Texas
- Duke University Marine Laboratory, Beaufort, North Carolina
- Friday Harbor Laboratory, Friday Harbor, Washington
- Hopkins Marine Station of Stanford University, California
- Boothbay Harbor Fishery Laboratory of the USFWS, Maine
- Oceangraphic Institute of the Florida State University, Alligator Harbor near Tallahassee, Florida
- Shellfish Laboratory of the USFWS, Milford, Connecticut
- Narragansett Marine Laboratory, Kingston, Rhode Island
- Gulf Coast Research Laboratory, Ocean Springs, Mississippi
- Pacific Marine Station, Dillon Beach, California
- Marine Biological Laboratory, Woods Hole, Massachusetts

Figure 1

Nansen bottles, the instrument oceanographers the world over use to collect samples of ocean waters, are attached in series to a cable which on the vessels of the University of California's Scripps Institution of Oceanography is worked over the side of the ship. The platform on which the technician stands is called the "bucket." Lowering and recovery of the bottle requires close cooperation between the technician and the winch operator (upper left).

Figure 2

Cores such as these, taken from the sediments at the bottom of the sea, may record millions of years of earth history. These were obtained on Capricorn Expedition in the southwest Pacific in 1952-53. Examining the cores is Milton N. Bramlette, Professor of Geology at the University of California's Scripps Institution of Oceanography (wearing glasses).

- Pacific Oceanic Investigations Laboratory, Honolulu, Hawaii
- Scripps Institute of Oceanography, La Jolla, California
- U.S. Fisheries Laboratory, Woods Hole, Massachusetts
- U.S. Fisheries Laboratory, Pensacola, Florida
- Miami Laboratory, Coral Gables, Florida
- U.S. Fisheries Laboratory, Beaufort, North Carolina
- Michigan Biological Station, Douglas Lake, Cheboygan, Michigan
- University of Miami Marine Laboratory, Coral Gables, Florida
- University of Minnesota Itaska Biological Station, Lake Itaska, Minnesota
- University of Washington School of Fisheries, Seattle, Washington
- University of Oklahoma Biological Station, Lake Texoma, Willis, Oklahoma

In addition, most states operate marine or fisheries installations which one might visit.

Students should make field trips to the seashore whenever possible to study and make collections. Several low-priced pocket field guides are available to assist in identifications.

Figure 3

The magnetometer measures variations in the earth's magnetic field. These offer clues to the structure of the earth beneath the sea. Here Ronald G. Mason works with a magnetometer used on Capricorn Expedition to the South Pacific in 1952-53. The Expedition is one of the more than 20 long expeditions carried out by the University of California's Scripps Institution of Oceanography since 1950.

Some of these will be mentioned later. For those who are not near enough to the oceans to visit the seashore, basic principles of hydrobiology may be learned from studying freshwater ponds and streams. A small aquarium can provide many interesting hours of observation and can demonstrate the effects of environmental factors on aquatic organisms. Leaflets of instructions on keeping aquaria can be obtained from the General Biological Supply House, 8200 South Hoyne Avenue, Chicago, Illinois, at the exact cost of printing and mailing—three cents per leaflet. Ask for Turtox Service Leaflets Nos. 5, 11, 20, 23, and 39, which pertain to aquaria and aquarium animals and plants. *The Aquarium*, a monthly periodical published by Innes Publishing Company, 210 North 13th Street, Philadelphia, Pennsylvania, may be of interest and value.

Once a year, usually late in August, marine scientists gather at a national meeting of the American Society of Limnology and Oceanography. It is often a very exciting time with new results and discoveries being presented. Anyone may attend. You can obtain information pertaining to the date, place, and schedule of activities for this meeting from any marine science laboratory listed above.

Reading is probably the surest assistant along the road to success. Potential marine scientists should avail themselves of free and low-cost articles published by such government agencies as the Texas Game and Fish Commission, Austin, Texas; the State Board of Conservation, Tallahassee, Florida; the U. S. Department of Interior Fish and Wildlife Service, Washington, D. C.; and, the U. S. Government Printing Office, Washington, D. C. A short list of books recommended for young people with an interest in the sea, are as follows:

Abbott, R. Tucker, *American Seashells,* D. Van Nostrand Company, Inc., 120 Alexander Street, Princeton, New Jersey, 1954. (A standard reference for the serious student; illustrations and color photographs) $12.50.

Beebe, William, *Exploring with Beebe,* Rand-McNally and Co., 8255 Central Park Ave., Skokie, Ill., 1932. (Adventure)

Beebe, William, *Half Mile Down,* Harcourt Brace Co., 383 Madison Ave., New York 17, N.Y., 1934. (Adventure)

Beebe, William, *Zaca Venture,* Harcourt Brace Co.,

Figure 4

Maxwell Silverman, engineer at the University of California's Scripps Institution of Oceanography, pushes overboard a 200-pound charge of TNT from the research vessel *Horizon*. Seismic studies of the sea floor depend on carefully timed man-made explosions. Varying sizes of charges are used. *Horizon* has a specially designed tilt table to facilitate casting explosives in the sea. The few Scripps technicians authorized to handle explosives have been specially trained in the work.

Figure 5

The flow of heat through the earth's crust into the ocean varies over the oceans. Measurements of the heat flow have been widely collected. Richard von Herzen (right), student at the University of California's Scripps Institution of Oceanography, and MacKenzie Keith, Pennsylvania State College, here handle the temperature probe as it is brought up from the depths on the research vessel *Spencer F. Baird* during Vermilion Sea Expedition to the Gulf of California in 1959. Visible on deck is the cylindrical case which houses the sensitive electronic recording instrument. Von Herzen has his hands on the long, slender probe itself. The probe is bent, which shows that the experiment was successful, for the instrument must have penetrated the sediments on the sea floor.

383 Madison Ave., New York 17, N.Y., 1938. (Adventure; information on field methods)

Berrill, N. Y., *The Living Tide*, Dodd, Mead Co., 432 Fourth Ave., New York 16, New York, 1951.

Breeder, Charles M. Jr., *Field Book of Marine Fishes of the Atlantic Coast*, G. P. Putnam's Sons, 210 Madison Ave., New York 16, N. Y., 1948. (A comprehensive illustrated pocket manual) $5.00.

Buchsbaum, Ralph, *Animals Without Backbones*, University of Chicago Press, 5750 Ellis Ave., Chicago 37, Ill., 1948. (Zoology) $5.00.

Carson, Rachel L., *Under the Sea-Wind*, Simon and Schuster, 630 Fifth Ave., New York 20, N. Y., 1941.

Carson, Rachel L., *The Sea Around Us*, Oxford University Press, 114 Fifth Ave., New York 11, N. Y., 1952. $4.95.

Carson, Rachel L., *The Edge of the Sea*, Oxford University Press, 114 Fifth Ave., New York 11, N. Y., 1955.

Coker, R. E., *This Great and Wide Sea*, University of North Carolina Press, Chapel Hill, North Carolina, $6.00.

Coker, R. E., *Streams, Lakes and Ponds*, The University of North Carolina Press, Chapel Hill, North Carolina, 1954. (For the general reader interested in inland waters) $6.00.

Coleman, John S., *The Sea and Its Mysteries*, W. W. Norton and O., 55 Fifth Ave., New York 3, N. Y. 1950. (Principles of marine science for the general reader)

Cousteau, J. Y., *The Silent World*, Harper & Brothers Publishers, 49 E. 33rd Street, New York 16, N. Y., 1953. (Story of undersea discovery and adventure; illustrated with photographs) $4.00.

Curtis, Brian, *The Life Story of a Fish*, Harcourt Brace Co., 383 Madison Ave., New York 17, N. Y., 1949. (Readable informal biography of fishes) $3.75.

Darwin, Charles, *The Diary of the Voyage of the H. M. S. Beagle*, edited by Nora Barlow, Cambridge University Press, 32 E. 57th St., New York 22, N. Y., 1934. (Account of exploratory voyage; a classic)

Dawson, E. Yale, *How to Know the Seaweeds*, Wm. C. Brown and Co., 215 W. Ninth Street, Dubuque, Iowa, 1956. (An illustrated manual for marine algae) $3.00.

Douglas, John S., *The Story of the Oceans*, Dodd, Mead, Co., 432 Fourth Ave., New York 16, N. Y., 1952.

Eddy, Samuel, *How to Know the Freshwater Fishes*, Wm. C. Brown Co., 215 W. Ninth Street, Dubuque, Iowa, $2.75.

Edmonson, Charles H., *Seashore Treasures*, Pacific Books, P. O. Box 558, Palo Alto, Calif., 1949. (Illustrated Hawaiian shore life)

Gorsky, Bernard, *Vastness of the Sea*, Little, Brown and Co., 34 Beacon St., Boston 6, Massachusetts, 1957. (Adventure) $5.00.

Guberlet, Muriel Lewin, *The Seashore Parade*, The Jaques Cattell Press, Lancaster, Pa., 1942.

Heyerdahl, Thor, *Ton-Kiki*, Rand McNally and Co., 8255 Central Park Ave., Skokie, Ill., 1950.

Hochbaum, H. A., *Travels and Traditions of Waterfowl*, University of Minnesota Press, 2037 University Ave. S. E., Minneapolis 14, Minnesota, 1955.

Hylander, Clarence J., *Sea and Shore*, The MacMillan Co., 60 Fifth Ave., New York 11, New York, 1950. (Recommended for younger students)

Jahn, T. L., *How to Know the Protozoa*, Wm. C. Brown Co., 215 W. Ninth St., Dubuque, Iowa, 1949. (Illustrated manual) $3.00.

King, T., *Water: Miracle of Nature*, The MacMillan Co., 60 Fifth Ave., New York 11, New York, 1955.

Kuenen, P. H., *Realms of Water*, John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, New York, 1955.

Figure 6

One of the ships used in oceanographic work.

La Monte, Francesca, *Marine Game Fishes of the World*, Doubleday and Co., Inc., Garden City, New York, 1952. (Illustrated pocket guide with descriptions, distributions, seasons, and tackle)

Latil, Pierre De, and Rivoire, Jean, *Man and the Underwater World*, G. P. Putnam's Sons, 210 Madison Ave., New York 16, New York, 1956. (History of exploring of the seas) $5.00.

Macan, T. T., and Worthington, E. B., *Life in Lakes and Rivers*, William Collins Sons, Inc., 425 Fourth Ave., New York 16, New York, 1951.

MacGinitie, G. E., and MacGinitie, Nettie, *Natural History of Marine Animals*, McGraw-Hill, 330 W. 42nd Street, New York 36, New York, 1949. (Good photographs; recommended as a reference)

Marmer, H. A., *The Sea*, D. Appleton and Co., 35 W. 32nd Street, New York 1, New York, 1930. (A scholarly account stressing physical oceanography)

Marshall, N. B., *Aspects of Deep Sea Biology*, Philosophical Library, New York, New York, 1954. (Illustrated integrated account of oceanic life; recommended for those with a keen advanced interest) $10.00.

Miner, Roy, *Field Book of Seashore Life*, G. P. Putnam's Sons, 210 Madison Ave., New York 16, New York, 1950. (Field guide to Atlantic Coast) $6.00.

Morris, Percy A., *A Field Guide to the Shells*, Houghton Mifflin Co., 2 Park Street, Boston 7, Massachusetts, 1951. (A pocket guide to Atlantic and Gulf Coast shells) $3.50.

Needham, James G., and Needham, Paul R., *A Guide to the Study of Fresh-Water Biology*, Comstock Publishing Company, Inc., 124 Roberts Place, Ithaca, New York, 1951. (For identification of aquatic invertebrate animals and aquatic algae) $1.00.

Figure 7

The research vessel *Horizon* of the University of California's Scripps Institution of Oceanography is a converted Navy sea-going tug. She is 143 feet long and has a cruising range of approximately 6,800 miles. Accommodations are available for 27 scientists and crew members. Operated by the University since 1949, *Horizon* has participated in several of the more than 20 long expeditions that the Institution has sent into the Pacific during the past decade.

Figure 8

Aerial view of the Institute of Marine Science with Aransas Pass Inlet and St. Joseph Island in the background. Photograph shows Classroom Building, Library-Office Building, Dormitory, Chemical and Equipment Building, and Dock Laboratory equipped with a running seawater system.

Norman, J. R., *A History of Fishes*, A. A. Wyn, Inc., 23 W. 47th St., New York 36, New York, 1951. $5.50.

Ommaney, F. D., *The Ocean*, Oxford University Press, 114 Fifth Ave., New York 11, New York, 1949. (Pleasant account of the ocean for the general reader)

Peterson, Roger T., *A Field Guide to Birds*, Houghton Mifflin Co., 2 Park Street, Boston 7, Massachusetts, 2 ed., 1947. (A general pocket guide to the birds but also suitable for shore and marsh birds) $3.50.

Pough, Richard H., *Audubon Water Bird Guide*, Doubleday & Co., Inc., Garden City, New York, 1951. (A pocket guide) $3.50.

Prescott, G. W., *How to Know the Freshwater Algae*, Wm. C. Brown Co., 215 W. Ninth Street, Dubuque, Iowa, 1954. $3.00.

Ricketts and Calvin, *Between Pacific Tides*, Stanford University Press, Stanford, California, 1952. (Recommended as a reference book) $6.00.

Russell, F. S., and Yonge, C. M., *The Seas*, Frederick Warne and Co., London, England, 1928. (Biological point of view) $6.00.

Shannon, Howard J., *The Book of the Seashore*, Doubleday-Doran Co., Garden City, New York, 1935.

Smith, Egbert T., *Romance of Sea Shells*, Published by the author, 1313 First Street, Fort Meyers, Florida, 1956. (Small booklet of Florida shells for the beginner) 75¢.

Spectorsky, A. C., *The Book of the Sea*, Appleton-Century-Crofts, Inc., 35 W. 32nd Street, New York 1, N. Y., 1954. (Collections of writings about the sea) $12.50.

Steers, J. A., *The Sea Coast*, Collins, 425 Fourth Ave., New York 16, New York, 1953. (A geologist's consideration of the sea coast) $3.75.

Storer, J. H., *The Web of Life: A First Book of Ecology*, Devin-Adair, 23 East 26th Street, New

York 10, N. Y., 1956. (Considers principles applying to both land and sea)

Tannehill, I. R., *The Hurricane Hunters*, Dodd, Mead Co., 432 Fourth Ave., New York 16, N. Y.

Verrill, A. Hyatt, *Wonderful Creatures of the Sea*, D. Appleton-Century Co., Inc., 35 W. 32nd Street, New York, N. Y. 1940.

Vilas, Curtis N. and Vilas, Naomi, *Florida Marine Shells*, the Bobbs-Merrill Company, Inc., Indianapolis, Indiana, 1952. $4.00.

Walford, Lionel A., *Living Resources of the Sea*, The Ronald Press Co., 15 E. 26th St., New York 10, N. Y., 1958. (Discussion of opportunities for research and expansion)

Wells, Harrington, *Seashore Life*, California State Department of Education, Sacramento, California, 1942.

Wilson, Douglas P., *They Live in the Sea*, Collins, 425 Fourth Ave., New York 16, New York, 1947. (Illustrated; recommended for young students)

Yonge, C. M., *The Sea Shore*, Collins, 425 Fourth Ave., New York 16, New York, 1949. (Account of life forms on British shores) $5.00.

Zim, Herbert S., and Shoemaker, Hurst H., *Fishes*, Simon and Schuster, Inc., 630 Fifth Ave., New York 20, New York, 1956. (A pocket guide to familiar American fresh and salt-water species) $1.00.

Zim, Herbert S., and Ingle, Lester, *Seashores*, Simon and Schuster, Inc., 630 Fifth Ave., New York 20, New York, 1955. (A beginners guide to marine life except fishes) $1.00.

Students are encouraged to visit their local libraries both for sources of information and material for leisurely reading relating to the seas. Your librarian can assist you in finding the above books and may suggest additional reading material in your field of interest. Scientific results are published in scientific journals which come out every month. Browsing through current issues is much fun. For general scientific and popular information let us recommend the following periodicals if you should care to subscribe.

*Sea Secrets*, published by The Marine Laboratory, University of Miami, Florida, and sponsored by The International Oceanographic Foundation.

*The National Geographic Magazine*, published by the National Geographic Society, Washington, D. C. $6.00 a year.

*Natural History*, published by the American Museum of Natural History, 79th Street at Central Park West, New York 24, New York. $5.00 a year.

High school seniors or beginning college students can sometimes qualify for summer positions as field and laboratory assistants in such research projects as characterization of fish populations, geo-biology of reefs, shell transport, metabolism of marine organisms, growth of marine plants, and sedimentation processes. Experience in these part time positions is valuable to the aspiring marine scientist.

Figure 9

The northern part of the campus of University of California's Scripps Institution of Oceanography. At the left is shown a portion of William E. Ritter Hall, a laboratory-and-office building; at the head of the steps is the entrance to the Thomas Wayland Vaughan Aquarium-Museum. The frame building at the right houses the headquarters of the La Jolla Biological Laboratory of the U. S. Bureau of Commercial Fisheries. The Laboratory works with the Institution in a cooperative study of the pelagic fisheries of California, a program in which three other research groups are also joined.

---

Some unusually distinctive kodachrome slides are now available from the Scientific Supplies Company, 600 Spokane Street, Seattle 4, Washington. The slides are the work of Mr. J. W. Thompson, a teacher of biology for more than twenty-five years, who decided that the available materials in this area were not as good as the ones that he could produce. The results indicate that Mr. Thompson's faith was well founded. A catalog of the available offerings is available from the above address.

---

The Northeastern Ohio Teachers Association held an outdoor education-school camping session on Friday, October 30, 1959. Our own Dick Weaver was the chief speaker and a variety of sessions made up the remainder of the program. Mr. William L. Howenstien, Cleveland Heights School Camp, was in charge.

# Gradient Agar Plates

EUGENE D. WEINBERG
*Indiana University, Bloomington*

Within the past few years a simple technique has been developed that increases tremendously the amount of information that can be obtained from a single petri plate culture. The technique is termed the gradient plate method and can be performed easily by anyone who can grow bacterial cultures.

The method involves solidification of a layer of agar medium while the petri dish is in an inclined position. The angle of inclination is such that the agar layer diminishes to nothing at one edge of the plate (see A in figure 1). An equal amount of agar medium is then added which is allowed to solidify while the plate is level, thus forming two complementary layers (see B in figure 1).

The types of gradients that can be established depend on the chemicals added to one or both portions of the agar medium before the portions are poured into the petri plates. Two very common types of gradient plates are those of pH and of antimicrobial compounds.

The pH gradient plates are prepared by adding 1.0 ml. of a sterile one-molar solution of $KH_2PO_4$ to 15 ml. of the melted cooled agar that is to be poured as the first layer, and 1.0 ml. of a sterile one-molar solution of $K_2HPO_4$ to the second 15 ml. portion of melted cooled agar that is to be poured as the second layer. We have found that 15 ml. quantities of sterile nutrient agar contained in tubes are convenient sources of the medium. The solutions of phosphates as well as the nutrient agar are previously sterilized by autoclaving. After solidification of the plates, the establishment of a pH gradient can be demonstrated by placing a filter paper strip that had been soaked in a pH indicator such as brom thymol blue on the surface of the plate in the direction of the gradient (see A in figure 2).

Two of the common uses of the pH gradient plate are: a) inocula of various microbial cultures can be streaked in the direction of the gradient to ascertain the optimum pH reactions for growth or pigment production (see B in figure 2), and b) cells of a single microbial culture that grows at all pH reactions in the plate can be spread over the entire surface of the plate and filter paper strips containing various antimicrobial substances can be placed on the plate in the direction of the gradient (see C and D in figure 2).

The antimicrobial gradient plates are easily prepared by the addition of an antimicrobial compound to the portion of plain nutrient agar to be poured as either the first or second layer. The actual concentration to be used will depend on the bacteria to be tested, the kind and potency of the compound, and the amount of inhibition desired. The appropriate concentration can easily be determined in preliminary tests in which each of several quantities of the compound is tested.

Two of the common uses of the antimicrobial gradient plate are: a) inocula of various microbial cultures can be streaked in

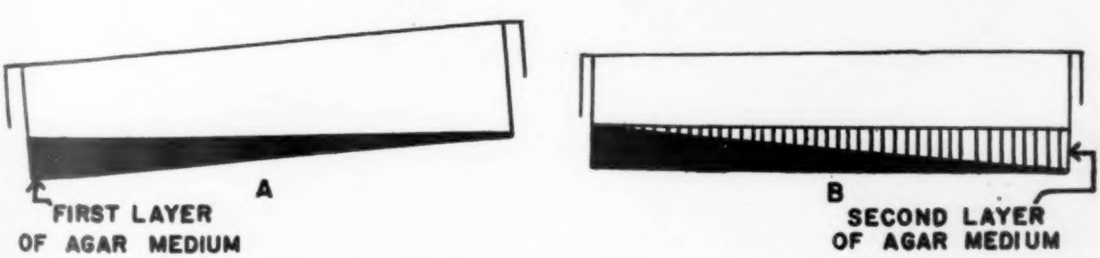



FIGURE 1. Preparation of gradient agar plate.

A. First portion of agar is poured into petri plate placed on an inclined board. The layer is allowed to solidify while the plate is held in the inclined position.

B. Second portion of agar is poured into petri plate placed on a level surface. The layer is allowed to solidify while the plate is held in the level position.

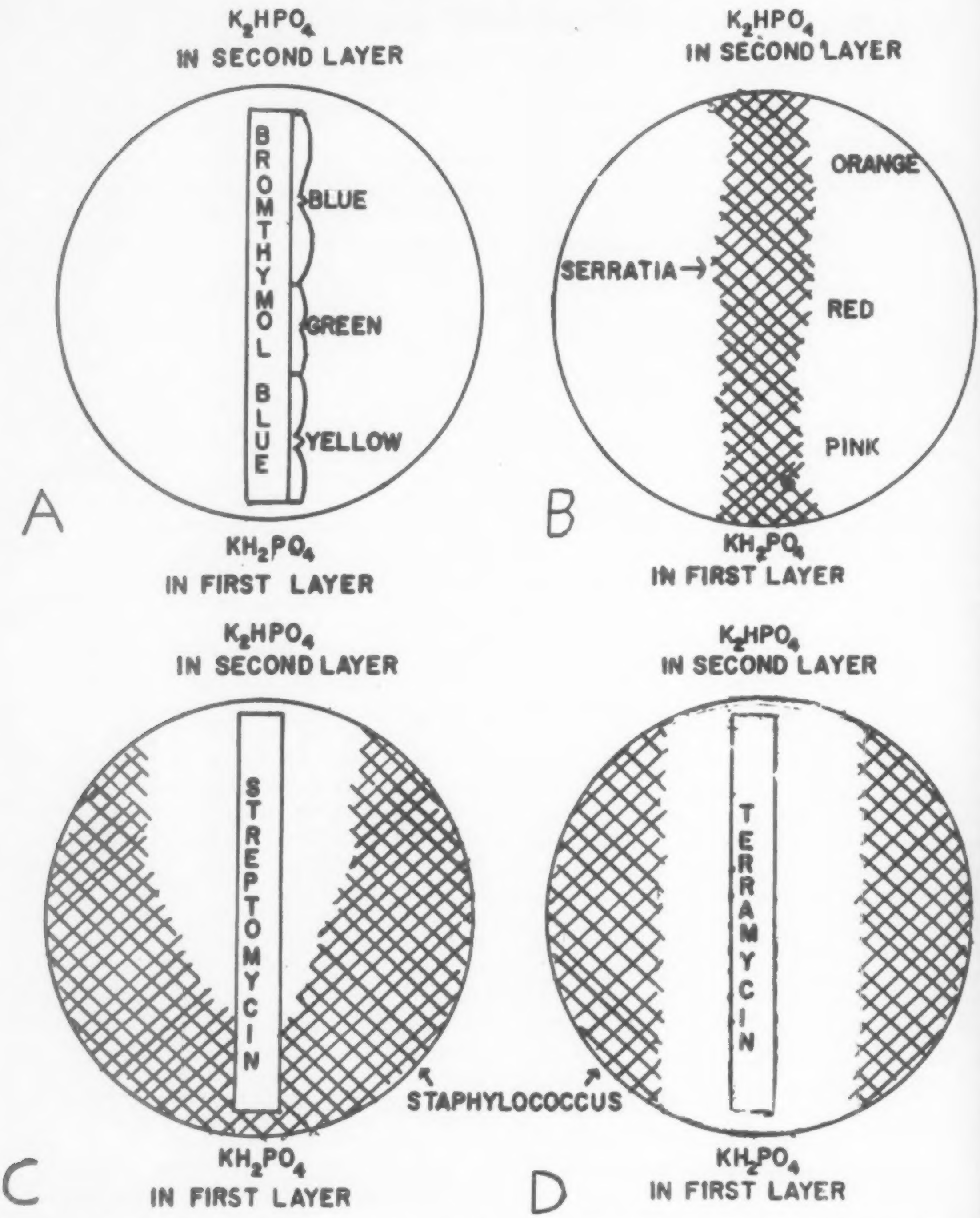



FIGURE 2. Results obtained with pH gradient plates. The acid region is at the bottom and the alkaline region at the top in each plate. The shading in plates B, C, and D represents bacterial growth.

A. Strip of filter paper that had been soaked in bromthymol-blue solution turns yellow in acid, green in neutral, and blue in alkaline regions of the uninoculated plate.

B. Plate inoculated by a single vertical streak and incubated with *Serratia marcescens* results in pink, red, and orange pigmentation of bacterial growth in the acid, neutral, and alkaline regions respectively.

C. Plate spread over the entire agar surface with streptomycin-sensitive strain of *Staphylococcus*

is inhibited by the antibiotic in the neutral and alkaline regions but not in the acid region.

D. Plate spread with terramycin-sensitive strain of *Staphylococcus* is inhibited by the antibiotic equally well in the acid, neutral, and alkaline regions.

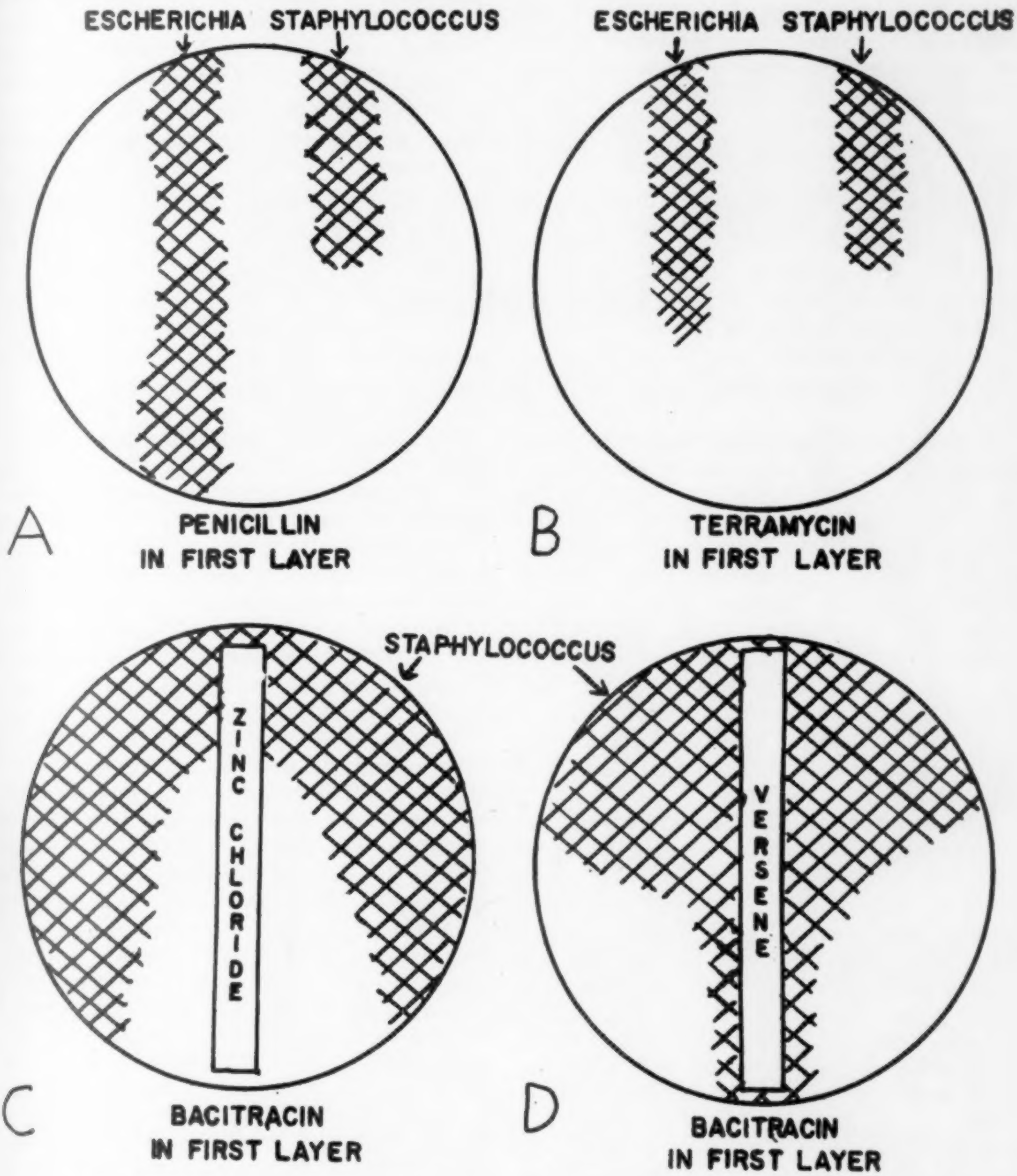



FIGURE 3. Results obtained with antimicrobial gradient plates. The antibiotic is incorporated in the first or lower layer which is thickest at the bottom of each plate in the four diagrams. The shading in each plate represents bacterial growth.

A. and B. Plates inoculated by single vertical streaks over the entire length of the agar surfaces. The antibacterial action of penicillin is much stronger and of terramycin is somewhat stronger toward *Staphylococcus* than toward *Escherichia*.

C. and D. Plates spread over the entire agar surfaces with bacitracin-sensitive strain of *Staphylococcus*. The antibacterial action of bacitracin is enhanced by zinc and suppressed by versene.

the direction of the gradient to compare the resistance or sensitivity of the strains to the antimicrobial compound (see A and B in figure 3); and b) cells of a single microbial culture can be spread over the entire surface of the plate and filter paper strips containing various substances that might affect the antimicrobial compound can be placed on the plate in the direction of the gradient (see C and D in figure 3).

References on the preparation and uses of gradient plates include the following:

Szybalski, W. Gradient plate technique for study of resistance. Science *116*, 46, 1952.

Streitfeld, M. M. and Saslaw, M. S. A strip gradient method for *in vitro* assay of bacterial sensitivity to antibiotics paired in various concentration ratios. Journal of Laboratory and Clinical Medicine *43*, 946, 1954.

Sacks, L. E. A pH gradient agar plate. Nature *178*, 269, 1956.

Weinberg, E. D. Double-Gradient agar plates. Science *125*, 196, 1957.

# Lazy Collector*

CHARLES HOWARD
*South Milwaukee Junior-Senior High School, South Milwaukee, Wisconsin*

If you're an ardent Ambystoma maculatum hunter like me, I'll break down and tell you my long used, top-secret method. With the right know-how, it will never fail. The only equipment you will need are the following items: a pillow, your collecting bag, and the ability to talk to a Calosoma scrutator and be understood. The next step, naturally, is to find one and outline your plan to him. With his services acquired, he goes about the business of putting the plan into action. While he does this, you find a nice comfortable spot, and, placing your pillow on the ground, sit back and wait for the results.

The first thing the Calosoma scrutator does is to hunt up a Grapemys geographica and locates the hiding place of the Ambystoma maculatum. Next he locates some Leucania unipuncta who are willing to cooperate with him. After a little confusion, the Leucania unipuncta get in order and form a line from the Ambystoma maculatum hideout to the place where a charming Reduvius personatus awaits in front of a dark, secluded cave entrance. But besides the Reduvius personatus, a Mastigoproctus giganteus lurks in the cave. And keeping him company there is a Mantis religiosa and the strongest Gasterophilus intestinalis ever seen. With all in place, the Calosoma scrutator reports back to you, and you pay him his fee of beer and sugar. You relax and watch the drama unfold.

The Ambystoma maculatum discovers the trail of Leucania unipuncta, and with the intent of having a huge feast, slowly advances upon them. But as they come up to the Leucania unipuncta trail, they tell the Ambystoma maculatum of the seductive Reduvius personatus at the other end of the line. The Ambystoma maculatum makes a bee-line for the end of the line, but just as he is about to claim his prize, out pops the Mastigoproctus giganteus who quickly strikes the poor fellow unconscious. While this is going on, the Mantis religiosa prays that he doesn't get stunned too effectively. Then the Gasterophilus intestinalis appears on the scene and carries the stunned Ambystoma maculatum to you where he is deposited in your collecting bag. When this has gone on, until you have all you think you will need for awhile, you pay off the rest of your helpers as you did the Calosoma scrutator. Then you pick up your pillow and collecting bag and head home. Mission accomplished!

*This paper was submitted by Mr. Nyles G. Stauss of the same school. It was written by one of his former students.

## New Charts

A new booksize chart shows the male and female body with explanatory index. Colored pages illustrate the organs of the chest and abdomen, muscular and nervous systems, heart and blood vessels, skeleton, and internal organs. Organs are pictured in an overlapping manner and can be viewed from front or back. Also available in life-size chart, the female model having an obstetrical supplement. Available from Otto Marschuetz, 3141 Sheffield Avenue, Chicago 14, Illinois.

# The Advanced Placement Program in Biology

EDWARD FRANKEL
*Bronx High School of Science, New York*

For more than a half century educators have been aware of the need for special methods in the education of academically gifted students. A variety of devices has been used to meet this challenge. Some educators have favored acceleration, others proposed enrichment and still others, taking a middle position, have suggested a combination of acceleration and enrichment.

The Advanced Placement Program, which may be classified as both acceleration and enrichment, was initiated in 1952 as the School and College Study of Admission with Advanced Standing. This study was based on the conviction that: 1. students of high ability can and should undertake more intensive and difficult work than they are at present required to take in the later years of high school, and 2. that at least a significant number of secondary schools are likely to be both able and willing to make curricular revisions providing enriched courses for such students.

In the fall of 1953, seven pilot secondary schools, The Bronx High School of Science among them, introduced the Program by establishing college-level courses in certain major subject matter areas for selected groups of very able students. Since this modest beginning there has been a continuous increase in the number of schools and students participating in the Program. By 1958, 356 secondary schools were offering college level courses to 3800 students who entered 300 different colleges in the fall of that year.

Secondary schools all over the country have evidenced so much interest in the Advanced Placement Program that a description of the experiences with the college-level courses in biology seems in order. These experiences, it is hoped, may be of help to schools interested in setting up college level courses.

At the Bronx High School of Science the Advanced Placement Course in biology is open to about twenty students selected from the senior class. The course meets for seven periods a week, two double laboratory periods and three single recitation periods. Three additional periods are set aside for student conferences, supplementary laboratory or recitation work, special lectures, seminars, and examinations.

Students are selected for the course from a list of eligible aspirants provided by the Guidance and Program Committee of the school. The teacher interviews all the candidates and makes the final selection on the basis of the following criteria: 1. intellectual and emotional maturity; 2. demonstrated superior scholastic ability; 3. genuine interest in biology and 4. recommendation of the former teachers and guidance counselor of the individual student.

### The Syllabus

The course content is based primarily on the syllabus suggested by the Biology Committee of the Advanced Placement Program.[1] This syllabus is a composite of typical introductory courses as currently taught in many colleges and universities. Fundamental concepts applicable to both plants and animals are selected for emphasis. Evolution is the dominating and integrating theme in which the interrelationships of the organism to its environment are stressed. Functional morphology based upon laboratory experiences with living organisms provides a continuous frame of reference. This fundamental syllabus has been constantly modified in terms of the background, interests, and ability of particular groups of students.

All of our students have taken elementary biology in the tenth year, and chemistry or physics in the eleventh year; all have had three years of mathematics.

On the basis of this common background, it has been possible to work out a curriculum in biology which has a biochemical-biophysical orientation. We have found it possible to present some topics even more extensively and intensively than the Advanced Placement Program requires. The topics receiving special attention are (a) the physico-chemical prop-

[1]The most recent syllabus of the Advanced Placement course in biology appears in the booklet published by the College Entrance Examination Board entitled "Advanced Placement Program Syllabus," 425 W. 117th St., N. Y., 1958, pages 25-31.

erties of protoplasm; (b) the biochemistry of carbohydrates, fats, proteins, and minerals; (c) enzyme study: oxidation-reduction reactions, ATP, hydrogen transport systems, and the citric acid cycle; (d) the structure, function and importance of DNA, and (e) the chemistry of photosynthesis in relation to respiration. The second semester concentrates on concepts relating to evolution. The work is focused on comparisons of morphological and physiological systems in plants and animals: the effect of transition from water to land habitation on body structure, circulation, respiration, excretion, reproduction and the nervous coordination. An integrated unit then presents particular aspects of genetics, embryology, and theories and mechanisms of evolution. This unit also lends itself to the introduction of statistical methods.

### Laboratory Work

One of the chief objectives of the laboratory experiences of this course is to familiarize the students with a broad variety of representative plants and animals in the hope that such a background will contribute to understanding the broad unifying principles of biology and thus produce deeper appreciation of them. The laboratory manual[2] selected for the course presents a study of various types of organisms which are representative of the principal plant and animal phyla. "The emphasis is on the individual organism, and the viewpoint is not primarily structural or taxonomic."

The manual was selected also because it emphasizes direct observations of organisms rather than mere recording of observations in the form of laboratory drawings. Wherever practicable, living organisms instead of preserved specimens are employed. The animals studied include living protozoa, planaria, earthworms, tubifex worms, lobsters, Daphnia, grasshoppers, fruit flies, clams, oysters, frogs, and rats. The plants studied include algae, molds, bacteria, liverworts, mosses, ferns, evergreens, and flowering plants.

Although half the zoology laboratory exercises in the manual are devoted to the study of the frog and the rat and call for the use of preserved injected specimens, a more accurate and realistic conception of these organisms is afforded by examining also fresh organisms. Our practice is to observe them first alive, and then to kill them and dissect them at once for observation of internal structures and internal activities such as peristalsis and heart beat. The dissection of freshly killed pregnant female rats provides excellent material for the study of reproduction. Freshly killed frogs may be used as a source of exciting protozoan and worm parasites as well as of living tissues such as blood, epithelium, and muscle. One should not overlook the gustatory appeal of lobsters, clams, oysters, shrimp, not to mention snails and squids and for the more daring souls, grasshoppers.

A cardinal principle in planning the laboratory work of the course is to create conditions which enable students to work independently. Each student is provided with individual laboratory specimens and is expected to supply himself with dissection materials, slides, cover glasses, lens paper, and the like. In addition, he receives a complete set of prepared microscope slides for the laboratory exercises each semester. Thus, each student is equipped to work independently, and there is little difficulty in permitting him to use the laboratory facilities during his study periods or even to carry on such work at home.

Deciding the sequence of laboratory work is a matter of experience, convenience, and taste. At the Bronx High School of Science, we prefer to study animals in the fall semester and plants in the spring so that we may utilize the spring days for botanical field trips. This arrangement enables us to enrich and motivate the study of botany, an area in which some students tend to exhibit less spontaneous enthusiasm and interest than in zoology. No matter what sequence is followed, planning the work for the entire year at one time is essential so that the delivery of materials—especially of live materials—from commercial suppliers can be scheduled in advance.

Since it has been impossible in our set-up to synchronize the topics presented in the recitation periods with those considered in the laboratory exercises, the two do not necessarily correspond to any given week. Perhaps this is just as well, since in a sense the two activities represent quite separate disciplines in biology; practice and theory. The divergence of recitation and laboratory topics is not disruptive because there is ample oppor-

[2]The manual presently in use is "Manual of Biology," Part I and II by Douglas Marsland, published by Henry Holt and Co., New York.

tunity for coordinating the material covered in laboratory and recitation. Towards the end of the fall semester when the topics being discussed deal with the comparative morphology and physiology of animals, the laboratory work provides the background and factual basis for this unit of work.

### Teaching Techniques

Although lecture is traditional at the college level, the teaching methods employed in our course vary considerably, ranging from seminar and round table discussion to simple recitation. The classroom technique most frequently used is discussion based on individual student reports. It is interesting to note that the students prefer this sort of program perhaps because it offers an opportunity to become more actively and positively involved in the learning process. For the teacher, this method involves considerable preplanning; it entails the preparation of a list of topics for reports, and the references, material, and bibliography for each topic. Seminars are conducted periodically to encourage "intellectual initiative and critical responsibility";[3] here the "group-topic" procedure is used. At the beginning of the fall semester, each student is assigned to become class "expert" on one of the organisms studied in the laboratory or on a phylum. He is expected to become thorougly familiar with the complete morphology and physiology of the organism not only on the basis of his personal laboratory work but also in terms of knowing the specialized literature on the subject. Towards the end of the semester, when the class discussions are centered upon the evolution of various animal or plant systems, each "expert" contributes a discussion of the organism for which he is responsible. For example, the discussion of the evolution of the excretory system consists of a series of reports by the "experts" on the excretory systems of the separate organism. The rôle of the teacher is to plan and direct the sequence of the reports and to coordinate the discussions.

### Term Papers

In the course of the academic year, students are required to read a given number of original scientific papers of current or historical importance. William Harvey's, "The Motion of the Heart and Blood,"[4] and Gregor Mendel's "Experiments in Plant Hybridization"[5] are read by the students. They then write an evaluation of these papers in the light of their historical importance. An excellent collection of significant historical papers is found in "Great Experiments in Biology" by Gabriel and Fogel;[6] this is available in an inexpensive paper back edition. Pertinent articles appearing currently in such popular scientific journals as "Scientific American" are often assigned. Each semester, at least one or two articles have happened to fit in perfectly with our course of study. Zinder's "Transduction" in the November 1958 issue and Kellworth's "Darwin's Missing Link" in the March 1959 issue were so appropriate as to be included in the required reading for this year.

In addition to evaluatory papers, each student is required to write a term paper describing a research problem in biology and a proposed experiment. The student is asked to select a specific area of interest and to prepare a digest of significant research in that area for the past five years and to list some of the unsolved problems in the area. The student is required to consult, either by personal contact or by correspondence, a person engaged in research in the area being studied and to find out precisely what experiments are being conducted. Finally, the student selects a specific problem and formulates plans for an experiment which will solve the problem. The purpose of the assignment is to familiarize students with research techniques, research workers, and research problems.

### Testing Techniques

Since the objective of the course is to present broad basic concepts and principles, testing techniques and instruments must be appropriately broad. In contrast to the present trend toward using objective tests, the most effective instrument for measuring a student's ability to grasp relationships, to make critical evaluations, and to express comparisons, has proved to be the essay question.

[3]The term seminar is here given the definition of R. F. Arragon, in "Education of the Gifted," Fifty-Seventh Yearbook of the National Society for the Study of Education, Part II, University of Chicago Press, 1958, p. 308.

[4]Published by Henry Regnery Co., Chicago, Ill., 1949.

[5]Published by Harvard Press. Cambridge, Mass., 1950.

[6]Published by Prentice-Hall, N.Y., 1955.

Responses are evaluated on the basis not only of content (correctness and relevancy of information) but also of written English (organization, precision of expression, management of emphasis, spelling, punctuation, and sentence structure). At first, students find difficulty in answering essay questions, probably because they have not been accustomed to presenting organized and sustained answers. It is sound and profitable procedure to hold conferences with students about their essays; at the conference the essays are critically evaluated and suggestions are made for handling essay questions.

The teacher can utilize previous Advanced Placement Examinations as a source of essay questions of the type students should be capable of answering. For example:

"Give an orderly, informative account of the occurrence, function, and importance of surfaces in biological systems."

"Compare and contrast the problems of reproduction faced by aquatic and terrestrial organisms. Give specific examples from both the plant and animal kingdom."

"A source of energy is of vital importance to an organism. Describe and compare the various methods whereby plants and animals obtain energy to meet their metabolic requirements. Direct your attention both to tht ultimate source of energy and to the specific processes employed by organisms to convert this energy into a usable form."

Student achievement in the laboratory may be evaluated by the "practicum" administered on an individual or group basis, by requiring written discussions of the laboratory work, by using commercially prepared laboratory test forms, or by grading specific laboratory exercises such as a dissection.

### Text and Reference Books

A prime requirement for a college-level course in biology is a college textbook: texts that stress biological principles are preferred to separate texts in zoology and botany. Experience indicates, however, that no one textbook can possibly cover the materials of a course of study in precisely the manner or the sequence proposed by the teacher. Separate supplementary reference books in the following areas are most desirable and helpful: botany, zoology, microbiology, cytology, biochemistry, plant morphology, physiology of both plants and animals, vertebrate zoology, invertebrate zoology, embryology, genetics, evolution, and ecology. For specific references in these subjects, see the appended list of recently published books. Periodicals and journals are extremely helpful. "Scientific American" is invaluable as a source of current scientific papers.

### The Advanced Placement Examination

In May of each school year, the College Entrance Examination Board administers examinations in each of the subject matter areas of the Advanced Placement Program. These examinations are prepared by a committee composed both of secondary school and college teachers. The Biology examination is a three hour test, of which two hours are devoted to essay questions, and one hour to multiple choice objective questions. Although the examination is open to all students, at the Bronx High School of Science all students enrolled in the college-level courses are required to take the examinations. Examination papers are graded by a marking committee also consisting of both secondary school and college teachers. A five point scale is employed in grading: "5" indicates "highest honors," "4" "honors," "3" "creditable," "2" "passing," and "1" "failing." Grades "2" through "5" are then passing college level grades and should be credited as such.

In July, the colleges receive for each entering student who has completed a college level course and an Advanced Placement examination in the subject, the examination booklet written the previous May, the marking Committee's grade, a copy of the examination question set, and an interpretation of the grades. In addition, the college receives a description of the college level course offered in the secondary school, the grade received in the course, and the secondary school's recommendation. On the basis of the evidence submitted, the college may (a) grant college credit, (b) offer advanced placement, (c) grant both credit and advanced placement, (d) postpone action, or (e) disregard the course and the examination and grant neither credit nor placement.

The reaction of the colleges to the Program is most encouraging. A survey of 360 colleges, conducted by the College Entrance Ex-

amination Board in the spring of 1958, "indicated 150 colleges granting appropriate placement to students who had taken Advanced Placement courses and who had performed creditably on the College Board's Advanced Placement examinations. Of the 360 colleges, 210 gave academic credit as well as placement. Some of these 210 colleges, to be sure, placed restrictions on the amount of college credit that could be earned in high school, but most allow credit without limit. Happily, among the earliest and firmest supporters of the Program are many of the outstanding colleges and universities in the country. Of the 150 colleges now giving placement only, without the award of credit, many will surely add the award of credit in a very few years."[7]

#### Student Performance on the Advanced Placement Biology Examination

The following are the scores received by the students in the college level biology classes in 1957 and 1958 at the Bronx High School of Science, as compared with the national scores:

that they entered ten different colleges. At these colleges, six had received advanced placement with credit; seven had been granted advanced placement alone; and four had received neither credit nor placement. Of the four, three had not asked for credit or placement, and one had enrolled in a school of engineering where he could not use the credit.

#### Student Reactions to the Program

In almost every case, the students answering the questionnaire considered the Advanced Placement courses an asset. The reasons given were the following:

"I acquired a real interest in biology."

"The courses enabled me to take advanced courses."

"The courses taught me how to take examinations."

Every student expressed the opinion that the decision to take the college level courses in high school has been a wise one. Not a single respondent experienced any difficulty as a result of having taken the Placement courses.

ADVANCED PLACEMENT EXAMINATION SCORES IN BIOLOGY FOR 1957 AND 1958 AT THE BRONX HIGH SCHOOL OF SCIENCE AS COMPARED TO THE NATIONAL SCORES

| | 1958 | | | | 1957 | | | |
|---|---|---|---|---|---|---|---|---|
| | *B.H.S.S.* | | *National* | | *B.H.S.S.* | | *National* | |
| *Score* | No. | % | No. | % | No. | % | No. | % |
| 5 | 2 | 9.1 | 15 | 7.1 | 0 | 0 | 4 | 2.7 |
| 4 | 11 | 50.0 | 41 | 19.5 | 12 | 70.6 | 35 | 23.8 |
| 3 | 7 | 31.8 | 72 | 34.3 | 5 | 29.4 | 56 | 37.8 |
| 2 | 1 | 4.5 | 53 | 25.2 | 0 | 0 | 37 | 25.0 |
| 1 | 1 | 4.5 | 29 | 13.8 | 0 | 0 | 16 | 10.8 |
| | 22 | | 210 | | 17 | | 148 | |

#### Follow-Up Study

During the school year 1956-57, 74 seniors were enrolled in six college level courses at the Bronx High School of Science. Of these, seventeen were registered in biology. In the fall of 1957, Mr. Bernard Manson, Director of Guidance, instituted a follow-up study of the whole group by means of a questionnaire which sought information concerning (a) the extent to which these students had received college credit and/or placement, and (b) their reaction to the Program.

The responses of the seventeen students who had been enrolled in biology showed

[7]David A. Dudley, "The Advanced Placement Program," *The Bulletin of the National Association of Secondary School Principals*, XLII, (Dec. 1958), p. 3.

In the general evaluation offered at the end of the questionnaire, the following ideas were expressed:

"I am very grateful for having been offered the opportunity."

"I got a great deal of satisfaction and enjoyment from the biology course."

"The course helped me decide on the field I want to enter."

"The course gave me an insight into college work."

"The on-your-own attitude was most important."

"I am forever indebted to my instructor in biology. He developed an awareness in me."

"The course was fascinating and well worth the work put into it."

### Evaluation of the Program

Looking back over the past six years, the writer endorses the evaluation of the Advanced Placement Program in Biology by Dr. David A. Dudley, former director of the Program:

> "It is of course easy to exaggerate the importance of the Program in which one has been himself directly involved. American education has for many reasons arrived in its history at a moment of self-examination and change. In that process, however, the Advanced Placement Program has been a sound and influential force among the catalysts. The Advanced Placement Program is a fulfillment. And it is also the promise of a new direction in our educational growth. It is imaginative. And it is a re-affirmation of our faith that scholarship is a matter of high consequence."[8]

### Recently Published Biology Texts and Reference Books

The following list of recently published biology texts and reference books may be useful to schools planning a reference library for a college-level course. No specific recommendations are made since the list is merely suggestive and not a complete listing of all the books in a given area. There are many other books, not included on the listing below which may be equally useful.

#### General Biology Textbooks

Alexander, G., GENERAL BIOLOGY, Crowell, 1956.

Brown, R. B., BIOLOGY, D.C. Heath, 1956.

Etkins, W., COLLEGE BIOLOGY, Crowell, 1950.

Hall and Moog, SCIENCE: A COLLEGE TEXTBOOK OF GENERAL BIOLOGY, J. Wiley, 1955.

Hardin, G., BIOLOGY, W. H. Freeman, 2nd ed., 1952.

Johnson, Laubengayer, and DeLanney, GENERAL BIOLOGY, H. Holt, 1956.

Marsland, D., PRINCIPLES OF MODERN BIOLOGY, 3rd ed., H. Holt, 1957.

Mavor, J. W., GENERAL BIOLOGY, 4th ed., Macmillan, 1949.

Milne and Milne, THE BIOTIC WORLD AND MAN, 2nd ed., Prentice-Hall, 1958.

Moment, G. B., GENERAL BIOLOGY, Appleton-Century-Crofts, 1950.

Pauli, W. F., THE WORLD OF LIFE, Houghton-Mifflin, 1949.

Simpson, Pittendrigh, and Tiffany, LIFE, Harcourt-Brace, 1957.

Villee, C. A., BIOLOGY, 3rd ed., W. B. Saunders, 1957.

Weisz, P. B., BIOLOGY, 2nd ed., McGraw-Hill, 1959.

Whaley, Breland, Heimsch, Phelps, and Schrank, PRINCIPLES OF BIOLOGY, 2nd ed., Harper and Bros., 1958.

#### Botany

Coulter, et al., TEXTBOOK OF BOTANY, World Press, 1957.

Fuller, H. J., PLANT WORLD, 3rd ed., H. Holt, 1955.

Fuller and Tippo, COLLEGE BOTANY, H. Holt, 1954.

Robbins, Weier, and Stocking, BOTANY, 2nd ed., J. Wiley, 1957.

Sinnott and Wilson, BOTANY: PRINCIPLES AND PROBLEMS, McGraw-Hill, 1955.

Weatherwax, P., BOTANY, 3rd ed., W. B. Saunders, 1956.

Wilson and Loomis, BOTANY, Dryden, 1957.

#### Zoology

Elliott, A. M., ZOOLOGY, 2nd ed., Appleton-Century-Crofts, 1957.

Guthrie and Anderson, ZOOLOGY, J. Wiley, 1957.

Hegner and Stiles, COLLEGE ZOOLOGY, Macmillan, 1951.

Moment, G. B., GENERAL ZOOLOGY, Houghton-Mifflin, 1958.

Storer and Usinger, GENERAL ZOOLOGY, McGraw-Hill, 1957.

Villee, Walker and Smith, GENERAL ZOOLOGY, W. B. Saunders, 1958.

#### Plant Morphology and Physiology

Audies, L. J., PLANT GROWTH SUBSTANCES, Interscience, 1953.

Bonner and Galston, PLANT PHYSIOLOGY, Freeman, 1952.

Eames and MacDaniels, PLANT ANATOMY, McGraw-Hill, 1947.

Meyers and Anderson, PLANT PHYSIOLOGY, Van Nostrand, 1952.

Smith, G. M., CRYPTOGAMIC BOTANY, Vol. I, McGraw-Hill, 1955.

Skoog, F. (ed.), PLANT GROWTH SUBSTANCES, U. of Wisconsin, 1951.

#### Cytology

Brachet, I., BIOCHEMICAL CYTOLOGY, Academic, 1957.

[8] David A. Dudley, *Bulletin of National Association of Secondary School Principals,* p. 5.

Bourne, G., CYTOLOGY AND CELL PHYSIOLOGY, 2nd ed., Oxford, 1951.

DeRobertis and Nowenski, GENERAL CYTOLOGY, Saunders, 1954.

Giese, A. C., CELLULAR PHYSIOLOGY, Saunders, 1957.

Swanson, C. P., CYTOLOGY AND CYTOGENETICS, Prentice-Hall, 1957.

### Animal Biochemistry and Physiology

Baldwin, E. H. F., DYNAMIC ASPECTS OF BIOCHEMISTRY, Cambridge, 1957.

Fruton and Simmonds, GENERAL BIOCHEMISTRY, J. Wiley, 1958.

Hawk, Oser, and Sommerfeld, PRACTICAL PHYSIOLOGICAL CHEMISTRY, 13th ed., Blakiston, 1954.

Best and Tayler, THE LIVING BODY, 4th ed., H. Holt, 1957.

Carlson and Johnson, MACHINERY OF THE HUMAN BODY, U. of Chicago, 1953.

Heilbrunn, L. V., OUTLINES OF GENERAL PHYSIOLOGY, 3rd ed., Saunders, 1952.

Fulton, J. F., HOWELL'S TEXTBOOK OF PHYSIOLOGY, 16th ed., Saunders, 1950.

Mitchell, P. H. A TEXTBOOK OF GENERAL PHYSIOLOGY, 5th ed., McGraw-Hill, 1956.

Prosser, C. L., COMPARATIVE ANIMAL PHYSIOLOGY, Saunders, 1950.

Turner, C. D., GENERAL ENDOCRINOLOGY, 2nd ed., Saunders, 1955.

### Vertebrates

Colbert, E. H., EVOLUTION OF THE VERTEBRATES, Wiley, 1955.

Berrill, N. J., THE ORIGIN OF VERTEBRATES, Clarendon, 1955.

Hyman, L. H., COMPARATIVE VERTEBRATE ANATOMY, U. of Chicago, 1943.

Romer, A. S., THE VERTEBRATE BODY, 2nd ed., Saunders, 1955.

Walker and Sayles, THE BIOLOGY OF THE VERTEBRATES, 3rd ed., Macmillan, 1954.

Weichert, C. K., ANATOMY OF THE CHORDATES, 2nd ed., McGraw-Hill, 1958.

### Invertebrates

Buchsbaum, R., ANIMALS WITHOUT BACKBONES, U. of Chicago, 1959.

Cater, G. S., A GENERAL ZOOLOGY OF THE INVERTEBRATES, Cambridge, 1957.

Chandler, A. C., INTRODUCTION TO PARASITOLOGY, 9th ed., J. Wiley, 1955.

Hyman, L. H., THE INVERTEBRATES, Vol. I, II, and III, McGraw-Hill, 1940.

Kudo, R. R., PROTOZOOLOGY, Thomas, 1954.

### Embryology

Arey, L. B., DEVELOPMENTAL ANATOMY, 5th ed., Saunders, 1953.

Barth, L. G., EMBRYOLOGY, Dryden, 1953.

Brachet, J., CHEMICAL EMBRYOLOGY, Interscience, 1950.

Dalcq, A. M., INTRODUCTION TO GENERAL EMBRYOLOGY, Oxford, 1957.

Huettner, A. F., COMPARATIVE EMBRYOLOGY OF VERTEBRATES, Macmillan, 1949.

Nelson, O. E., COMPARATIVE EMBRYOLOGY OF VERTEBRATES, Blakiston, 1953.

Patten, B. M., FOUNDATIONS OF GENERAL EMBRYOLOGY, Oxford, 1957.

### Genetics

Dobzhansky, T., GENETICS AND THE ORIGIN OF SPECIES, Columbia U. Press, 1951.

Darlington, C. D., EVOLUTION OF GENETIC SYSTEMS, Basic Books, 1958.

Goldschmidt, R., THEORETICAL GENETICS, U. of California, 1955.

Kempthorne, D., AN INTRODUCTION TO GENETIC STATISTICS, J. Wiley, 1957.

Lerner, I. M., GENETIC HOMEOSTASIS, J. Wiley, 1954.

Scheinfeld, A., THE NEW YOU AND HEREDITY, Lippincott, 1950.

Sinnott, Dunn and Dobzhansky, PRINCIPLES OF GENETICS, 5th ed., McGraw-Hill, 1958.

Snyder and David, THE PRINCIPLE OF GENETICS, 5th ed., Heath, 1957.

Srb and Owen, GENERAL GENETICS, Freeman, 1952.

Winchester, A. M., GENETICS, 2nd ed., Houghton-Mifflin, 1958.

### Evolution

Boyd, W. C., GENETICS AND THE RACES OF MAN, Little, Brown and Co., 1950.

Shull, A. F., EVOLUTION, McGraw-Hill, 1951.

Simpson, G. G., THE MEANING OF EVOLUTION, Yale U., 1949.

Moore, R., MAN, TIME, AND FOSSILS, Knopf, 1953.

### Ecology

Allee, et al., PRINCIPLES OF ANIMAL ECOLOGY, Saunders, 1949.

Carson, R. L., THE SEA AROUND US, Oxford, 1951.

Clarke, G. L., ELEMENTS OF ECOLOGY, Wiley, 1954.

Odum, E. P., FUNDAMENTALS OF ECOLOGY, Saunders, 1953.

### Disease and Immunity

Burdon, K. L., TEXTBOOK OF MICROBIOLOGY, Macmillan, 1958.

Frobisher, M., FUNDAMENTALS OF MICROBIOLOGY, 6th ed., Saunders, 1957.

Pelczar and Reid, MICROBIOLOGY, McGraw-Hill, 1958.

Stanier, R. Y., MICROBIAL WORLD, Prentice-Hall, 1957.

---

# BIOLOGY IN THE NEWS

Brother H. Charles, F.S.C.

WHERE EVOLUTION STANDS TODAY, Lincoln Barnett, *Life*, October, 19, 1959, pp. 96-113.

Impressive pictures of what may have been and text concerned especially with the development of vertebrates. You will want at least two copies of this article.

THE GREAT VIRUS TRACKDOWN, Ruth and Edward Brecher, *Family Circle*, October, 1959, pp. 32-33, 83-88.

A readable account of the general characteristics of viruses and of their activities with some specifics about polio, mumps and measles, and the reactions of the human body to these disease causers.

THE PERENNIAL MAGIC OF SOMETHING GROWING IN THE HOUSE, *McCall's*, October, 1959, pp. 92-99.

Excellent pictures with brief descriptions of plants which are easily cultivated in the home. Besides being good bulletin board material it will be useful in inspiring students to raise plants for themselves.

WHEN YOU SEE THIS—ACT, Gilbert Cant, *Sports Illustrated*, October, 19, 1959, pp. 80-92.

The banding of birds has resulted in much information about the travels and ages of birds. This article gives some history of bird banding and how people can cooperate in accomplishing the purposes of bird banding.

FALLOUT AND YOUR FAMILY'S HEALTH, Walter Goodman, *Redbook*, November, 1959, pp. 58-59, 104-107.

How harmful to humans is the radiation resulting from bomb tests? This article gives answers gleaned from the opinions of experts in atomic science. The ideas expressed can aid in correcting some faulty impressions and attitudes.

THE ERA OF NEW VIRUSES, Greer Williams, *Saturday Evening Post*, October 10, 1959, pp. 30, 98-100.

A stimulating account of the work of teams of virologists and of their efforts to conquer some diseases, even the common cold. It stresses the need for teamwork in scientific experiments. It may inspire some students to a career in science.

NEW CLUES IN SEARCH OF CANCER CURES, Steven M. Spencer, *Saturday Evening Post*, October 31, 1959, pp. 19-21, 56-60.

Will fungi and other plant life growing in soil yield substances for the cure of cancer? This is an interesting account of the work of several large laboratories which are culturing soils from most parts of the world in an effort to secure the answer.

SLAUGHTER AND SALVATION, Peter Matthiessen, *Sports Illustrated*, November 16, 1959, pp. 82-96.

This article describes some of the drastic, senseless reduction of wild mammals which occurred in North America in the past hundred years and the agencies now working to preserve the remaining forms. This should be read by anyone interested in conservation.

---

## Wyoming State Flower

Mr. René A. Pellet, Biology Department, High School, Rock Springs, Wyoming, has collected a number of the state flowers of Wyoming, and is willing to send them to any students who wish such specimens. Students desiring these should send Mr. Pellet a 9″ x 12″ self addressed, stamped envelope with the request. These will be sent out until the supply is exhausted.

---

## NSTA Annual Meeting

The National Science Teachers Association's annual meeting will be held in Kansas City, March 29-April 2, 1960.

All sessions will emphasize evaluation and improvement in "Current Science and the K-12 Program." The convention headquarters hotels are the Muehlebach and the Phillips. Speakers include Dr. Linus C. Pauling, Dr. Walter H. Brattain, Dr. George B. Kistiakowsky, and Dr. John R. Heller.

# Laboratory Exercises in Plant Physiology for High School Biology Courses*

CHARLES W. HAGEN, JR.
*Indiana University, Bloomington, Indiana*

Discussions between high school and college science teachers invariably turn to methods of presenting material or to the development of stimulating projects for gifted students. Frequently the college teacher hears of limitations imposed by equipment and budget. This article is an outgrowth of such discussions. Its purpose is to demonstrate that neither equipment nor budget must be elaborate to provide an instructive laboratory program from which techniques may be derived which the individual student can extend to levels that are really research efforts.

There is a secondary purpose, however, which is less apparent in the material which follows and therefore requires a bit of elaboration at this point. Ordinarily we justify the inclusion of laboratory work in science courses by the need for comprehension of the "scientific method" by all segments of the population. There are secondary benefits for those few who will continue in science, but for those who enter other occupations, profits are to be derived from familiarity with the techniques and mental manipulations through which our civilization is making its most rapid advances. Yet too often our laboratory programs resolve themselves into a series of disconnected experiments which simply illustrate points already made vividly clear in the classroom. Such a program may provide some limited insight into the nature of an experiment but it fails completely to illustrate the way in which scientific knowledge pyramids, the manner in which one set of inferences depends upon earlier deductions, and the weakness of deductive structures built upon faulty foundations. These aspects of scientific method cannot be illustrated by individual experiments, however well designed. Nevertheless they are an integral part of the laboratory program and should be impressed upon all students. To some extent the arrangement of experiments can aid in establishing the proper attitude, but far more depends upon intelligent commentary from the teacher and a full concern on his part for something more than the consequences of the individual exercise.

To these ends the experiments described below have been arranged in levels, each level being dependent upon the consequences of the preceding. These levels may be described as: 1. Accepted information, 2. Fundamental techniques, 3. Qualitative demonstrations and 4. Quantitative measures. As categories of information the terms have no general significance in scientific procedure. Here they represent levels of increasing complexity which serve to illustrate the dependence of one deduction upon another and thus illustrate this aspect of the scientific method.

Many of the experiments included are old ones although some of these have been modified to eliminate common difficulties. All are selected from the domains of photosynthesis and respiration which are considered in every biology course. Similar programs could be prepared for other special areas within biology. Each exercise is so designed that all equipment could be constructed from materials salvaged or purchased in local grocery and hardware stores at very low cost.

*Level one—Accepted information.* Each modern scientist must take much of the information he uses on faith. He must do this critically, of course, but he cannot hope to repeat all earlier experiments and, anyway, inconsistencies in the fundamental data are most frequently revealed through incongruences which develop in the elaborated structure. Even at the elementary level, no science is independent of the others and biology is probably least so, being dependent upon chemistry, physics, and mathematics for the knowledge which permits a mechanistic inter-

*Much of the material included in this paper has been presented as part of the program of the Institute for Teachers of High School Biology at Indiana University. The author, Professor of Botany at Indiana University, found time to write while holding a Guggenheim Fellowship and a Fulbright Research Award.

pretation of biological events as well as for the techniques required to measure these events.

Information essential for comprehension of subsequent experiments may be summarized as follows:

1. Knowledge of molecular structure, of chemical reactions acccording to law, and of conservation of mass in ordinary reactions.
2. Knowledge of the composition of the atmosphere in terms of volumes and pressures.
3. Comprehension of the equivalence of energy in its various forms and of the conservation of energy.

This sounds formidable yet these matters are all touched upon in less direct terms in general science at lower levels. Thumbing through a stack of the *Weekly Science Reader* will convince you that the students have been exposed. Nevertheless, because biology appears early in most high school curricula, the biology teacher is forced to accept responsibility for a review and clarification of at least this much physics and chemistry at some time during the biology course. The trick is not to go too far. To teach that reactions proceed according to rule does not necessarily imply a complete explanation of valence law or of factors governing the direction and rate of reaction. Individual reactions can be dealt with as they appear and the necessary initial knowledge is only that reactions occur which are subject to limitations imposed by chemical structure and physical conditions.

*Level two—Fundamental techniques.* Proceeding from the "Accepted information" we can now develop some basic chemical reactions which will enable us to illustrate changes that take place during photosynthesis and respiration.

2.1 Source of carbon dioxide gas: The customary method of generating carbon dioxide is through exposure of limestone, marble or other carbonate to dilute acid. Vinegar serves adequately as the acid. Perhaps more familiar to students at this stage is the carbon dioxide content of carbonated beverages. Ample supplies of carbon dioxide may be obtained by shaking a tepid bottle of cola. Addition of a powdered material, such as blackboard chalk, will hasten gas release.

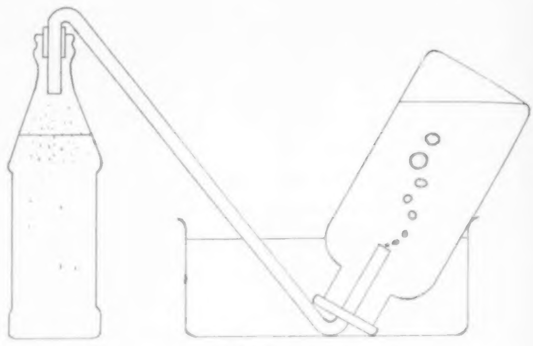


Figure 1

The gas should be collected over and through water as in figure 1. (Passing the gas through water eliminates need for a foam trap). Stopper the bottle of collected gas but have ready a two-hole stopper bearing an entry and a delivery tube. Use within a few hours.

2.2 Tests for carbon dioxide. Two tests are necessary, both depending upon reaction with a base to form a carbonate. To produce a visible precipitate force the gas (by replacement with water) through a test tube containing a filtered 2% solution of slaked lime ($Ca(OH)_2$, or use $Ba(OH)_2$). A white precipitate of $CaCO_3$ forms. Use air as a control but explain that some $CO_2$ is present in air.

Fill a test tube with carbon dioxide and invert this in a dish of 10% caustic soda (sodium hydroxide). Absorption of the gas will be demonstrated by the rise of liquid into the test tube. Again use air as a control.

2.3 Release of carbon dioxide from sodium bicarbonate. Into a screw-top one-pint preserving jar pour a filtered 2% solution of slaked lime (or of barium hydroxide) to a depth of one-half inch. In a small wide-mouth bottle, such as an individual cream jar, place a 5% solution of baking soda (sodium bicarbonate). Insert the small jar into the larger and seal as in figure 2. Establish the control in the same manner but replace the baking soda solution with tap water. Compare the precipitates formed in the slaked lime after 24 hours.

2.4 Test for starch. Use tincture of iodine or prepare iodine-potassium iodide solution as follows: Grind together in a mortar one

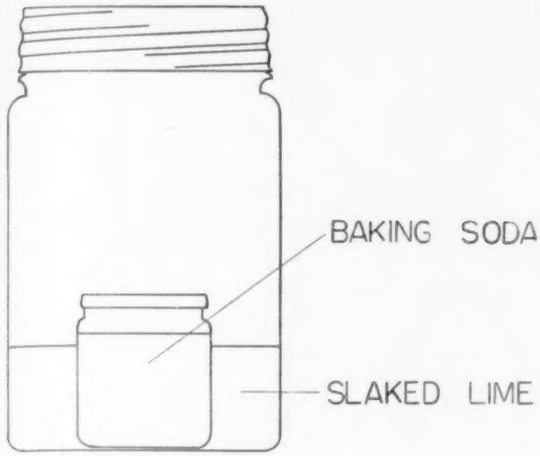



Figure 2

gram of iodine and one gram of potassium iodide. Dissolve in one hundred millilitres of water and store in a rubber-stoppered bottle.

Drop this reagent on a lump of cornstarch, on a slice of potato, and on common negative materials such as sugar and salt. The blue or black color is a reliable test for starch. Point out the food value of starch.

Use the reagent to illustrate the presence of starch in plant leaves. Select a leaf of geranium or coleus which has been exposed to sunlight for several hours. Kill it by dipping in boiling water for a few seconds, then remove the chlorophyll by immersing in hot alcohol for several minutes. Flatten the leaf in a dish and cover with the iodine reagent. After two minutes rinse in tap water and spread against a white background.

*Level three—Qualitative demonstrations.* We have begun already to build an inductive structure. We learned a test for starch and used it to demonstrate the existence of this compound in plant tissues. We learned some attributes of carbon dioxide and are able to demonstrate its release from carbonate solutions into air. We now utilize these deductions to elucidate specific processes which take place within the plant.

**Photosynthesis**

3.1 With a single compound experiment, one can demonstrate that leaves make food (starch) but this process requires light, carbon dioxide, and green tissue.

Equipment:

- 4 screw-top 1-pint preserving jars with gaskets intact
- 4 small bottles or vials
- 2 geranium or coleus plants, one of which shows green-white variegation. Both plants should be darkened for two days preceding the experiments.
- 5% baking soda (sodium bicarbonate) solution
- 10% caustic soda (sodium hydroxide) solution
- tincture of iodine or iodine-potassium iodide reagent
- 95% alcohol (denatured alcohol is suitable) or acetone.

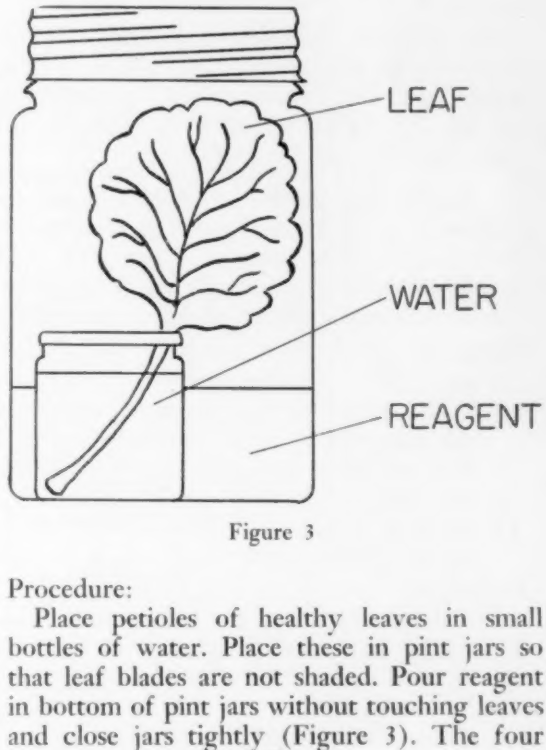



Figure 3

Procedure:

Place petioles of healthy leaves in small bottles of water. Place these in pint jars so that leaf blades are not shaded. Pour reagent in bottom of pint jars without touching leaves and close jars tightly (Figure 3). The four jars are arranged as follows:

A. Leaf should be green; reagent should supply carbon dioxide to air (5% baking soda); strong natural light should be provided.

B. Leaf should be green; reagent should supply carbon dioxide to air (5% baking soda); jar should be placed in a dark cupboard.

C. Leaf should be green; reagent should remove carbon dioxide from the air

(10% caustic soda); light should be provided.

D. Leaf should be variegated; reagent should supply carbon dioxide (5% baking soda); light should be provided.

The illuminated jars should stand in bright natural light supplemented throughout the night by a 100-watt bulb at two feet. Remove leaves in the next available period without losing identity of the treatments. (Positive results may be obtained in as little as 90 minutes with direct sunlight but the leaves may remain enclosed for at least 48 hours). Kill the leaves in boiling water then remove chlorophyll with warm alcohol. Test for starch with iodine.

Results:

Starch will form under condition A where requirements are satisfied, but not in B or C where light and carbon dioxide, respectively, are missing. In D, starch forms only in the green portions of the leaf.

3.2 Oxygen production during photosynthesis may be demonstrated by a classical method which is not too dependable. The plant material must be in good condition and chlorinated water should be avoided.

Equipment:

1 large jar

1 funnel to which is attached a short rubber tube and a clamp. The whole should fit completely into the large jar.

1 test tube or small bottle

1 sizeable bunch of Elodea, Cabomba, or other aquatic plant.

Procedure:

Fill the jar with water to near the top, insert the plants, and cover them with the funnel. Open the clamp to allow the funnel and attached tube to fill with water, then close the clamp. Add a pinch of baking soda to the water to ensure a supply of carbon dioxide, then place the whole apparatus in strong light (Figure 4).

Results:

Bubbles released from the plants collect under the funnel and may be transferred to an inverted test tube full of water by opening the clamp. Test for oxygen by inserting a glowing splint.

3.3 In experiment 3.1, the requirement for green tissue was demonstrated. In this

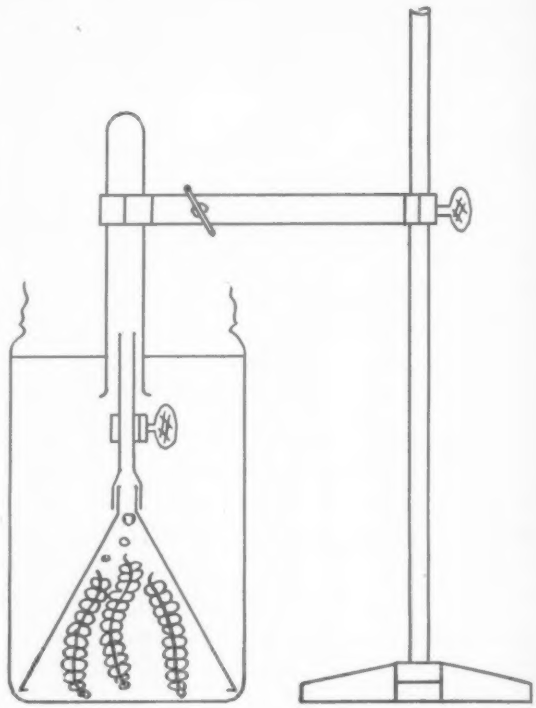


Figure 4

experiment the complexity of the plastid pigments is shown through simplified adsorption chromatography.

Equipment:

2 (or 3) screw-top preserving jars

1 test tube or small bottle

Glass tubing (about 3 mm O.D.)

Carbon tetrachloride

95% alcohol

Anhydrous sodium sulfate (or plaster of paris)

Filter paper (Whatman #1 is suitable but other qualitative grades should serve)

Green leaves (Blue-grass is excellent; or compare green and white areas of variegated coleus. Geranium is not satisfactory.)

Procedure:

Crumple green tissue, place in small bottle or test tube, barely cover with alcohol, and leave overnight in a dark place. Decant the clear green solution and use within 24 hours (Figure 5).

Pour carbon tetrachloride to a depth of ½-inch in one pint jar. Add a bit of anhydrous sodium sulfate or (plaster of paris) and close tightly.

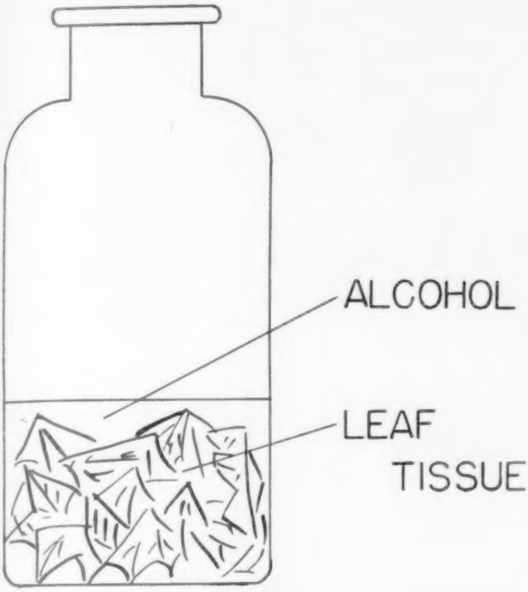



Figure 5

Cut filter paper sheets which will fit easily into the jar when rolled into a cylinder. Store in another jar over sodium sulfate or other desiccant. Draw a pencil line one inch from the bottom of each sheet before use.

Draw glass tubing to a fine tip and using this as a pen, mark a narrow line of chlorophyll extract (about 1½ inches long) along the pencil line on one sheet of filter paper. Repeat six to ten times or until mark is deep green. Sheet must dry between applications (Figure 6).

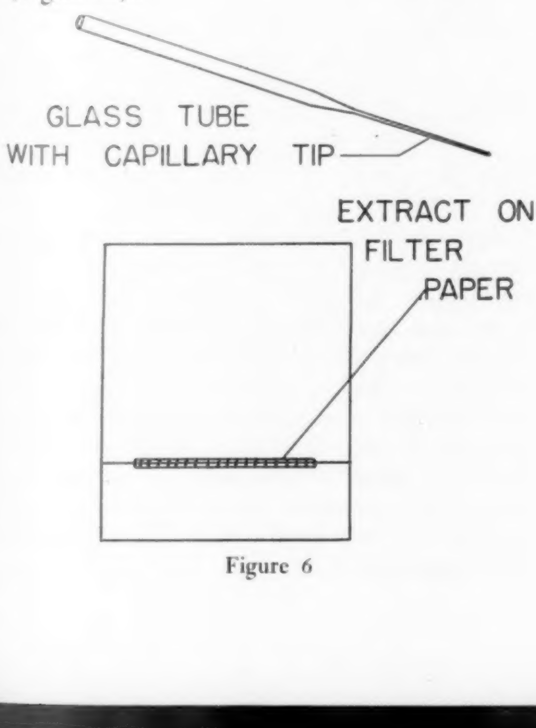



Figure 6

When thoroughly dry roll sheet into a cylinder with line of extract near the bottom. Secure with a paper clip. Stand in carbon tetrachloride and seal jar (Figure 7). Remove and dry before the liquid reaches the top of the paper (about 10 to 15 minutes).

Results:

Examine the paper fresh, since colors fade, especially in the light. The pigments should appear as colored bands in the following sequence from top to bottom: carotenes (orange-yellow at the solvent front), xanthophylls (one or more yellow bands) chlorophyll a (blue-green), chlorophyll b (yellow-green).

Except for the participation of water, which can be demonstrated only indirectly, the elements of the generalized equation for photosynthesis have now been presented in qualitative fashion. This may be expressed in words: "With light as a source of energy, plant tissues which contain chlorophyll utilize carbon dioxide (and water) in the production of foods (starch) and oxygen." Note that experiment 3.7 is pertinent to this story in that it indicates the fate of the energy provided as light. The requirement for protoplasmic constituents other than chlorophyll may be illustrated, if desired, by including a dead leaf in experiment 3.1.

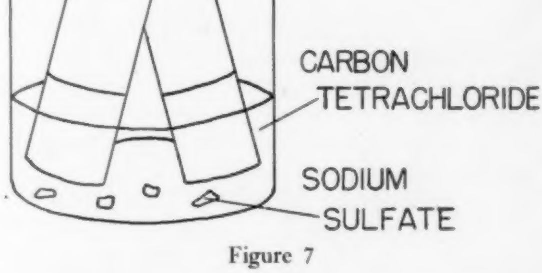



Figure 7

### Respiration

3.4 Carbon dioxide production during human respiration is easily demonstrated and provides a reference point for studies with plants.

Equipment:
2 balloons
2 medicine droppers (or glass tubes constricted at one end)
2 test tubes or small bottles
2% slaked lime (or 2% barium hydroxide) filtered
tire pump

Procedure:
Fill one balloon by mouth; the other with the tire pump. Clamp shut and attach each to a medicine dropper. Allow each balloon to discharge slowly through 2% slaked lime in a test tube (Figure 8).

Results:
White precipitate should form in abundance in the tube through which the balloon filled with exhaled air discharges. The other should remain clear or exhibit only slight cloudiness.

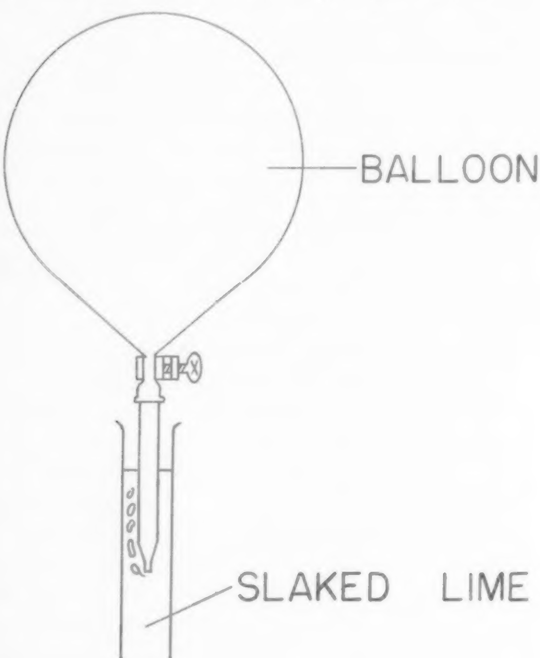



Figure 8

3.5 Plants, as well as other organisms, produce carbon dioxide.

Equipment:
4 screw-top one-pint preserving jars
2 small bottles such as individual cream bottles
2% slaked lime or 2% barium hydroxide
Germinating seeds
Green leaves
Clean quartz, pea gravel, or other inert material which is not carbonate and not organic.

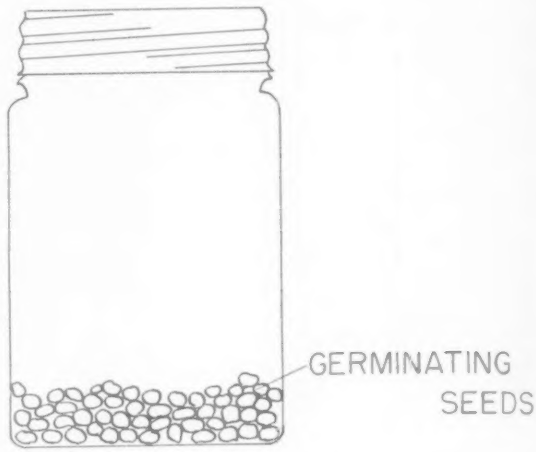



Figure 9

Procedure:
Prepare the four preserving jars as follows:

A. Add a handful of moist germinating seeds. Close and place in light (Figure 9).

B. Add a quantity of moist inert material approximately equal to the seeds in A, close jar and place in same location as jar A.

C. Place the petiole of a green leaf in water in the cream bottle, then insert this bottle in the preserving jar. Close the jar and place in continuous light (Figure 10).

D. Repeat the arrangement of jar C but place in a dark cupboard.

After 24 hours pour an equal small quantity of filtered 2% slaked lime into each jar, opening the lid gently and for as brief a time as possible. Swirl the jars gently, then tip to observe the precipitate in the added reagent.

Results:
A precipitate of carbonate should be abundant in A and D where respiration is the dominant process but should not appear in C where photosynthesis has removed the carbon dioxide nor in B which contained nonliving material.

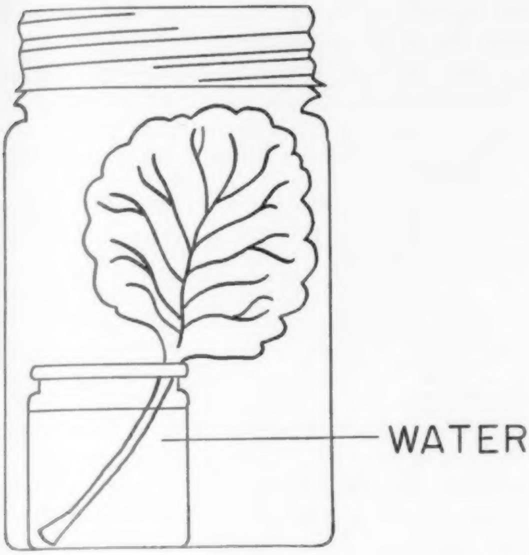



Figure 10

3.6 The simplest methods of demonstrating oxygen utilization during respiration depend upon a knowledge of the composition of air. Two methods are available: one is volumetric; the other is manometric and requires a supply of mercury.

Method 1

Equipment:

2 cylindrical 100-ml. graduates. (Other sizes may be used, or mark ten equal volumes to approximately ½-inch of the top on two large test tubes or other cylindrical vessels.)

2 wide-mouth jars into which the graduates fit freely when inverted.

1 J-shaped glass tube which fits in the wide-mouth jar.

10% caustic soda solution

Germinating peas or other seeds

Non-corrosive wire or screen

Procedure:

Prepare a piece of crumpled wire or screen to support seeds in the graduate when inverted. Measure the volume of the wire plus six to ten peas by observing the displacement when immersed in water in a graduate. Empty the graduate, drain the seeds and wire, and replace in the graduate at about the 50-ml. level. Invert the graduate in a wide-mouth jar about ¾ full of 10% caustic soda. Raise the level of the caustic soda inside the graduate to the 100-ml. mark (approximately) by allowing air to escape through the J-shaped tube. Read the volume with the liquid levels equal inside and outside the graduate (Figure 11).

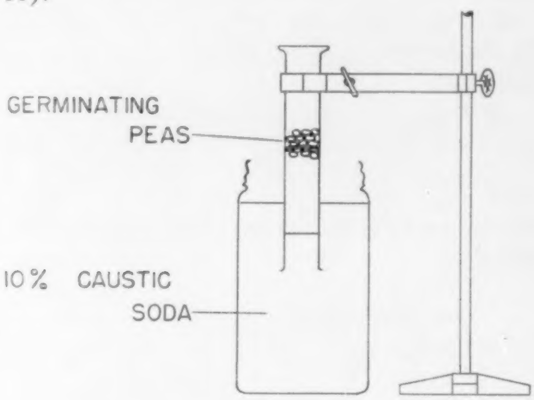



Figure 11

The second graduate should be arranged in the same fashion but with the seeds omitted.

After 24 hours measure the final volume in each of the graduates (again with the levels equal inside and out). Repeat at 48 hours.

Results:

The control may change volume as a reflection of changes in temperature or barometric pressure. The volume of the other graduate should be corrected percentage-wise by changes in the control.

The volume of gas in the cylinder containing the seeds should decrease by 20%, or the percentage of oxygen in air, but the change is usually somewhat less.

Method 2

Equipment:

1 large-mouth bottle

2 small stable bottles such as individual cream bottles

1 single-hole rubber stopper to fit the bottle in which is inserted the short arm of a J-shaped glass tube. The long arm of the tube should exceed 16 centimeters.

Germinating wheat or other seeds

A supply of mercury

10% caustic soda

Procedure:

Distribute moist germinating seeds as a layer ½-inch thick in the large bottle. Carefully insert a small bottle half full of 10% caustic soda. A cylinder of filter paper dipped

in the caustic soda and extending above the mouth of the small jar will speed absorption of carbon dioxide. Insert the stopper tightly and arrange in such fashion that the longer end of the J-tube dips into mercury contained in the second small jar (Figure 12).

Results:

As oxygen is consumed and carbon dioxide absorbed by the caustic soda, mercury rises in the glass tube. The maximum rise is equivalent to the partial pressure of oxygen in air, or 20% of the prevailing atmospheric pressure.

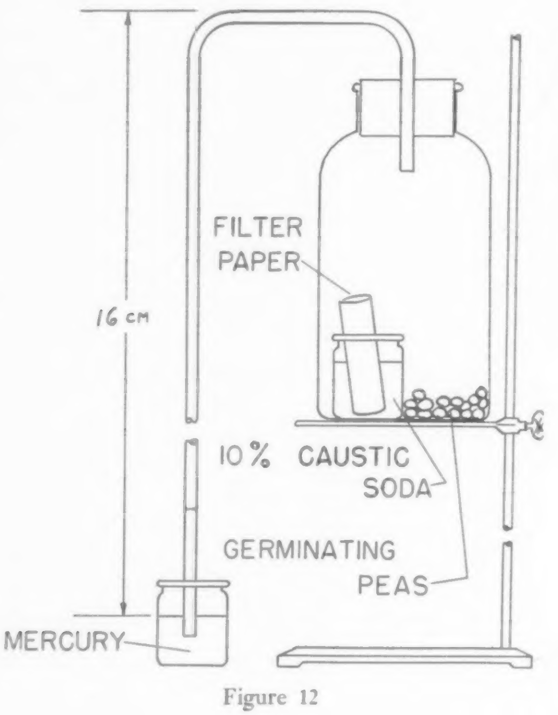



Figure 12

3.7 Students should be familiar with the use of fuel as an energy source. This demonstration should convince them that sugar, a representative food, could serve as fuel. Moreover it reveals something of the role of catalysts.

Equipment:

1 cube of sugar
Cigarette ashes

Procedure and results:

Attempt to ignite a clean block of sugar with a match. The sugar will melt and carbonize but will not burst into flame. However, if the cube is first dipped into cigarette ashes the mixed oxides will catalyze the reaction and the sugar will burn readily.

3.8 Heat production during respiration is readily demonstrated. It may be necessary to advise the students that energy appearing as heat is wasted as far as the plant is concerned.

Equipment:

2 thermos bottles of equal size
2 thermometers inserted in corks which fit the thermos bottles
3% formalin solution
Viable wheat seed

Procedure:

Soak ½ of the wheat seed for 4-5 hours in running water. Place in 3% formalin for 3-4 minutes to kill bacteria and fungus spores then wash in several changes of water which has been boiled and cooled to room temperature. Fill the first thermos bottle with these seeds, insert the thermometer, and record the temperature. Prepare the second thermos bottle in the same manner but use the dry seeds (or inert material) (Figure 13).

Observe the temperature changes at intervals for 24 hours.

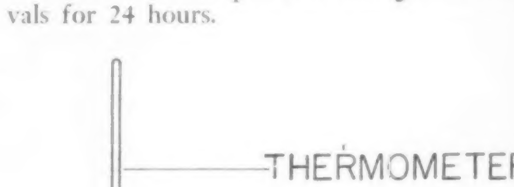



Figure 13

Results:

The soaked seeds respire rapidly and the escaping heat raises the temperature several degrees above level in the second thermos.

In this series (3.4 to 3.8), food is recognized as a source of energy. Respiration yields energy and carbon dioxide with utilization of oxygen. Release of water through respiration is difficult to demonstrate. The series could be expanded to show the disappearance of food (starch or dry matter) during respiration and the failure of work performance (germination) when respiration is restricted (by oxygen deficiency).

*Level four—Quantitative measures.* To proceed beyond the demonstrative level of the preceding experiments generally requires some method for measuring relative rates of a process under varied external conditions. Rate measurements may impose demands for equipment and techniques which, when excessive, quench the ambition at an early stage. It is possible, however, to modify experiments of level three in rather simple fashion to allow use of the same principles for quantitative measures, thus permitting the young enthusiast to set up a research program which arises naturally from his class work. Needless to say, the teacher may also employ the equipment to reveal finer points of respiration or photosynthesis. Three approaches are described here but a number of others are suggested in the list at the end of this paper.

4.1 Rate of photosynthesis by bubble-counting—a development of experiment 3.2.

Equipment:

Test tubes or small bottles

Elodea, Cabomba, or other aquatic plants

Procedure:

Invert a freshly cut sprig of Elodea in a test tube containing pond water and expose to light (Figure 14). Bubbles should be released from the cut stem at a rate which is roughly proportional to the rate of photosynthesis. Select the best performer among several sprigs and use the same sprig for successive treatments which do not damage the plant. A small pinch of baking soda at the beginning of each test will ensure an adequate supply of carbon dioxide.

This system responds rapidly to changes in temperature or light intensity. A micro-funnel devised to trap the bubbles and release them at uniform size is said to eliminate some of the difficulties inherent in the method.

4.2 Respiration rate by carbon dioxide production.

Equipment:

1 Winchester or other large bottle

4 cylinders or bottles of approximately ½-pint capacity

1 thermometer

Glass tubing, about 7-mm O.D.

Glass tubing, about 15-mm O.D.

Rubber stoppers to fit as illustrated (Figure 15)

2% barium hydroxide, filtered

0.5N potassium hydroxide

Calibrate the large bottle (Figure 15, A), marking 500-ml. intervals, then fit with a stopper and two glass elbows cut short within. Connect one elbow to a water tap. Connect the second elbow to a glass tube which leads into a tallish cylinder (B) which will be filled with 0.5N potassium hydroxide. This inlet tube should extend to the bottom of the cylinder and open through a drawn tip. A second tube, opening at the top of the cylinder, should lead to the bottom of a jar (C) which will contain 2 per cent barium hydroxide, and this, in turn, should be connected in a similar fashion to a wide-mouth jar (D) which will serve as a respiratory chamber for the experimental material. The stopper of the respiratory chamber also bears a thermometer and an exit tube. The next unit (E) is critical, for in it the carbon dioxide produced by the respiring tissue must be completely absorbed. This requires slow, turbulent passage of the gas through the absorbing liquid (0.5N po-

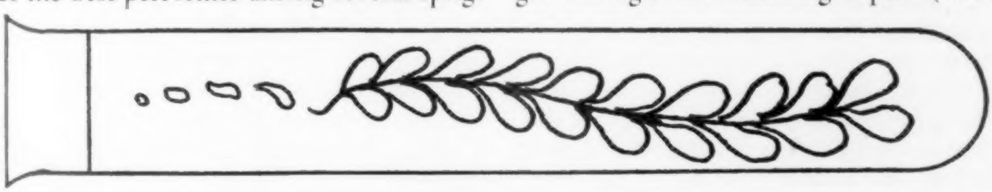


Figure 14

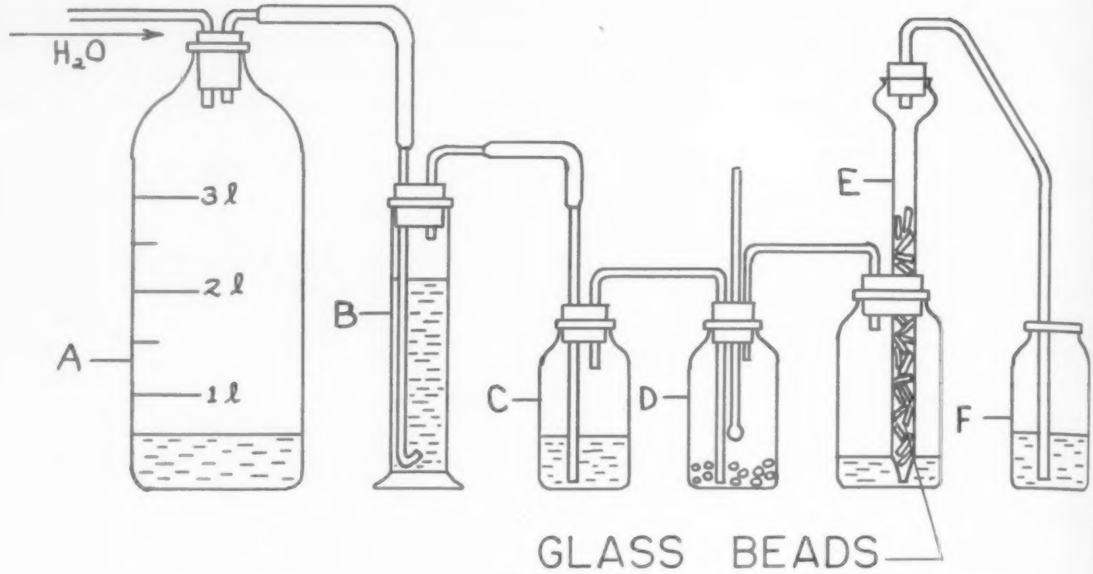


Figure 15

tassium hydroxide), while ease of measurement demands use of a small quantity of liquid. The Pettenkorfer tube (Figure 16) is the simplest form to construct and perhaps more satisfactory than the tower illustrated as figure 15, E. Many other designs are feasible. Whatever the design, the fluid capacity *while in operation* should be measured with water before an experiment is performed. The final jar (F) will contain barium hydroxide solution and may be open to the air.

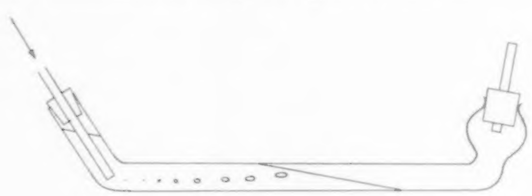


Figure 16

Procedure:

A slow stream of water from the tap forces air successively through B, where carbon dioxide is removed, C, which indicates the efficiency of B, and D, where the tissue produces carbon dioxide to be absorbed in E. F checks the efficiency of absorption in E and prevents backward diffusion of carbon dioxide from the atmosphere. Test the flow and check the tightness of stoppers before introducing the tissue. The flow rate should be adjusted to allow several hours respiration.

Introduce the tissue and record time and temperature. During the run, titrate a sample of the 0.5N potassium hydroxide against 0.5N hydrochloric acid. Immediately after the run, titrate the absorbing solution in E. From the difference between the two titrations, calculate the *total* carbon dioxide production in $\mu$g per hour per unit quantity of tissue at the measured temperature.

This apparatus serves best for study of temperature effects or for comparisons of respiratory rates at different stages of development (e.g. of germinating seeds or of ripening fruits).

4.3 Volumetric measurement of oxygen consumption during respiration.

Equipment:
- Levelling bulb (or glass funnel)
- 10-ml. graduated pipette
- 125-ml. flask
- Large thin-walled vial
- Small vial to fit in 125-ml. flask
- Glass tubing, approx. 7-mm. O.D.
- Rubber tubing
- Rubber stoppers
- Two screw clamps
- Kerosene tinted with Sudan IV or other fat stain
- Mercury
- 5% potassium hydroxide
- Germinating seeds or other respiring material

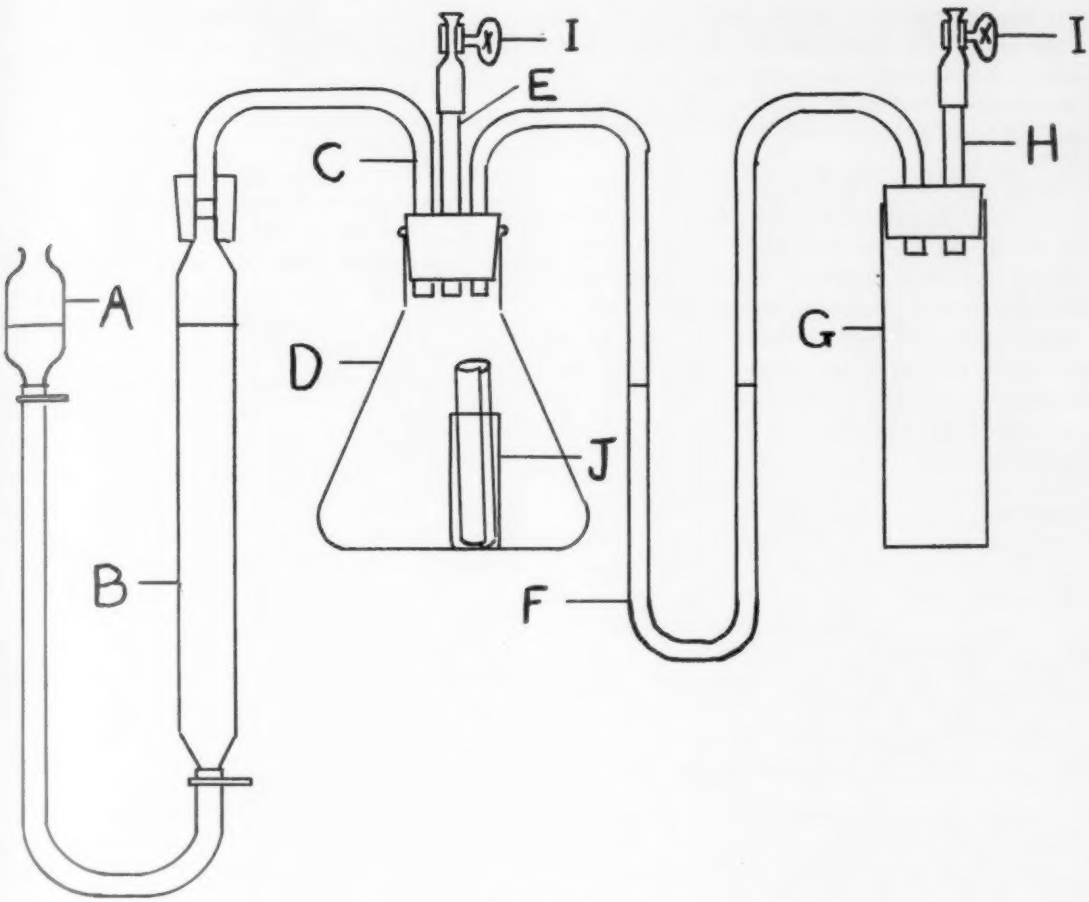



Figure 17

Wire about 18 inches of rubber tubing to the bottom of the levelling bulb (Figure 17, A) and to the delivery tip of the pipette (B). Insert the mouthpiece of the pipette halfway into a stiff rubber stopper. Into the other end of the stopper insert a broadly U-shaped glass tube (C) the other end of which passes through a three-hole rubber stopper selected to fit the 125-ml. flask (D). The three-hole stopper should also bear a straight tube (E) and one end of a manometer (F) formed from glass tubing. The other end of the manometer passes through a two-hole stopper which fits the vial (G) and carries a straight tube (H). Fit both straight tubes (E, H) with short lengths of rubber tubing which can be closed with screw clamps (I). The arms of the manometer (F) may be bent at right angles to the plane of the body in such a way that the flask and vial are brought side by side. This allows their insertion into a water bath for temperature regulation.

Draw into the manometer sufficient tinted kerosene to rise about half way in each arm. Support the whole apparatus on a ring stand with the flask easily removed. Add sufficient mercury to the levelling bulb to allow full range of the pipette graduations by raising or lowering the bulb. Set the mercury near the lower limit of the graduations while the clamps (I) are open.

Procedure:

Place germinating seeds or other tissue in the bottom of the flask and embed in this a small vial (J) containing 5% potassium hydroxide solution and a roll of filter paper which extends above the rim. With the clamps open, allow the flask and vial to adjust to the adjacent temperature. Mark the level of the fluid in the manometer and close the clamps. Record the time and the level of mercury in the pipette. Within a few moments

the manometer fluid should move *toward* the flask and away from the vial. At appropriate intervals (usually 10 minutes) return the manometer fluid to its original level by slowly raising the levelling bulb, then read the new level on the pipette.

This instrument is a constant pressure respirometer which works quite well if all connections are tight. As carbon dioxide produced by the respiring tissue is absorbed rapidly in the potassium hydroxide solution, consumption of oxygen effects a decrease in pressure and volume within the flask. Because no changes occur within the vial, the gas contained therein may be restored to its original pressure by returning the manometer fluid to its initial level. This operation also restores the gas within the flask to its original pressure. Changes in mercury level, therefore, provide direct measures of volume changes within the flask, and these can be considered volumes of oxygen consumed by the respiring tissue. Volumes should be converted to standard conditions of temperature and pressure and referred to the quantity of tissue employed. With some experience it is possible to run two or more instruments in parallel.

In this section certain sample techniques and equipment have been described. The apparatus may be employed for many different experiments, some of which are suggested in the list which follows. Included in the list, however, are a few projects which will demand some ingenuity in design of further equipment.

### Suggested Projects

1. Volumetric analysis of gas sampled during photosynthesis or respiration by a confined plant.
2. Effect of ambient conditions (temperature, pressure, light intensity etc.) on photosynthesis or respiration.
3. Effect of volatile inhibitors of photosynthesis or respiration. Try chloroform, ether (explosive!) or hydrogen sulfide (poisonous!).
4. Inhibition and stimulation of photosynthesis or respiration by water soluble compounds.
5. Changes in respiratory rate during seed germination or fruit maturation.
6. Determination of the respiratory quotient of germinating seeds.
7. Effect of wavelength of light on photosynthesis.
8. Absorption spectra of leaf or flower pigments (involves construction of a spectrophotometer).
9. Xanthophylls of leaves or flowers revealed by chromatography.

## New Films

ADVENTURING IN CONSERVATION, an informational film on basic conservation principles and practices, is available for showing for upper elementary and junior high school conservation units, school camp programs, state and local conservation groups, camp leadership programs, and summer camp programs. The film is produced by the Audio-Visual Center, Indiana University in cooperation with the American Camping Association and the Lilly Endowment, Inc.

ADVENTURING IN CONSERVATION shows boys and girls studying the formation and composition of the soil, planting trees, and building diversion dams. A forest ranger explains to the children the importance of not harming small animals, such as snakes, turtles, and toads, and teaches them how to properly extinguish a fire. Young people are shown making useful and attractive articles from saplings, seeds, and bark, as the narration explains that these materials must be selected with great care, and that in some areas nothing should be removed.

---

Two new titles, CONTROLLED PHOTOGRAPHIC LIGHTING and EXPOSURE, have been added to the series of Indiana University produced films on the preparation of audio-visual materials.

Designed especially for use in still photography and motion picture courses as well as camera clubs, the 16mm sound motion pictures are available in color or black and white.

---

## Reserpine

Chemists have split the "dual personality" of the mental drug reserpine, and produced two new reserpine modifications—one an agent for lowering blood pressure and the other a tranquilizer. Reserpine, which has been used successfully in the treatment of mental illness, acts as both a tranquilizer and a hypotensive agent (a drug that lowers blood pressure). The new hypotensive agent is about as strong as reserpine in this respect but only one-twentieth as active as a tranquilizer in animal tests, Dr. H. B. MacPhillamy, chemist of Ciba Pharmaceutical Products, Inc., Summit, N. J., said.

# Techniques for the Unit on Circulation

DAVID F. SYGODA
*Andrew Jackson High School, Queens, New York*

I. Circulation in the fish's tail.

In our attempts to demonstrate circulating blood many of us use the tail of the goldfish. Weren't you often disturbed when pupils exclaimed, "I don't see a thing?" The fish had flipped its tail, and it was only self control that kept you from "flipping your lid." Many devices have been improvised to solve this problem. The following set-up is simple to prepare and has been very effective.

Using a dip net remove a goldfish from its tank or battery jar. Place it on a regular microscopic slide (3″ x 1″). Using a one inch roll of bandage, restrain the fish by wrapping the bandage around both the fish and slide from the operculum to the tail. Be sure to leave the operculum free for breathing movements and the tail free for observation purposes. Place this set-up in the bottom of a Petri dish. Cover the fish with water from the tank. If the thickness of the goldfish is such that it cannot be covered with water, then cover the operculum with moistened cotton. Now spread the tail fin and focus under low power of the microscope.

This set-up has been used as a demonstration so that a class of 38 had time to study the fish's circulation. At the end of this period, the fish was returned to its tank. It swam about as a normal fish should to the relief of the class's anxiety about the fate of the goldfish.

With an honor class, the technique was shown to the class. The class was then divided into committees of six each. Each group was provided with needed materials and fish and set up its own demonstration. Previous class discussion had led to some ideas as to what they could learn by observing circulating blood in the tail of a fish. Each committee was asked to discover and discuss their answers to such problems as:

How can you tell whether the blood is passing through a vein, artery, or capillary?

How does movement of blood through an artery differ from that through a vein?

II. A demonstration to show how exercise helps to circulate blood.

A. Obtain the following materials:
   1. a U tube—½″ diameter
   2. 3 one-hole stoppers to fit the U tube
   3. glass tubing, rubber tubbing, rubber sheeting or a balloon, red ink.

B. Prepare the following:
   1. Convert a one-hole stopper into a valve by stapling a piece of rubber sheeting to the narrower end.
   2. Slice one of the stoppers 3/8″ thick and convert it into a valve.
   3. Prepare 2″ lengths of glass tubing by fire polishing both ends.

C. Assemble the set-up.
   1. Insert the "valve stopper" and glass tubing into one arm of the U tube. Insert the "sliced stopper valve" into the other arm—about one inch up—with the valve side down.
   2. Fill the U tube with the red ink. Stopper the free arm of the U tube with the other rubber stopper and inserted glass tubing. Connect the rubber tubing to both ends of glass tubing. The assembled set-up should correspond to the set-up as shown in diagram A.

D. Show the set-up to the class. Have pupils identify the various parts:
   1. What part of the circulatory system does the rubber tubing represent?
   2. What do these represent (point to the valves)?
   3. In which blood vessels are they found?
   4. How does walking or other forms of exercise help the heart circulate blood? If the class gives the correct answer, illustrate the point made by repeated squeezing and relaxing of the rubber tubing. This causes the "blood" to

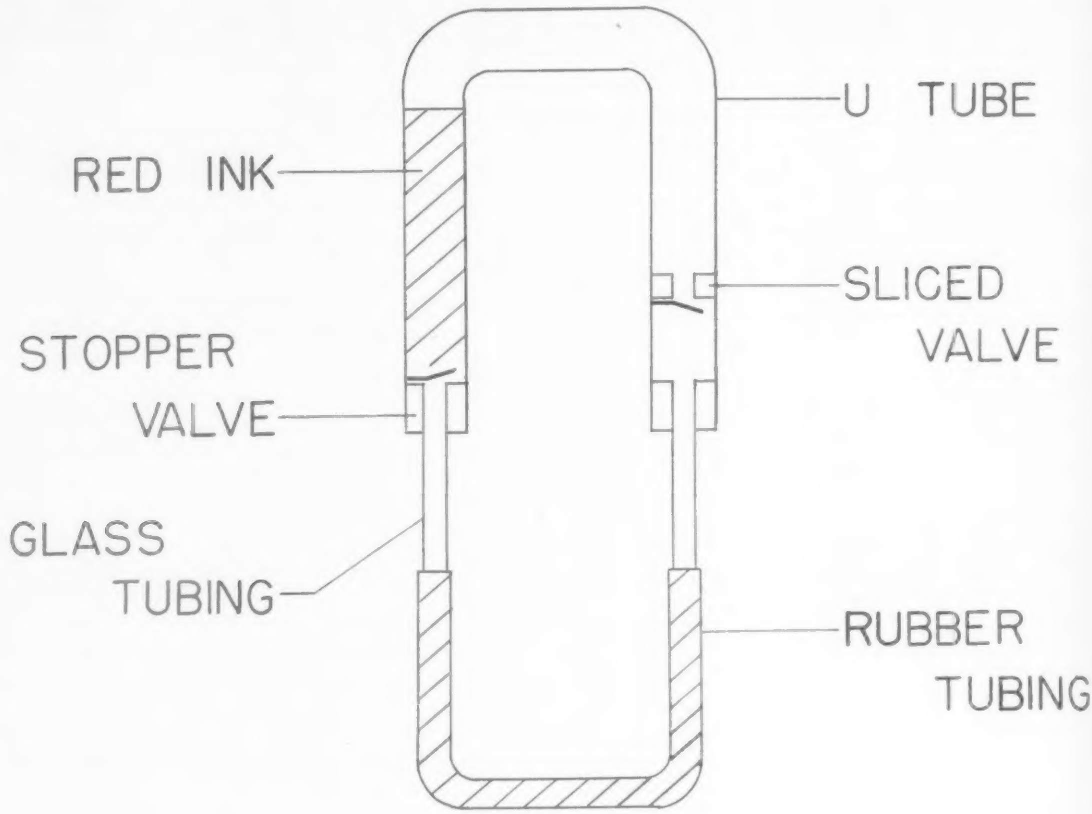



Diagram A

circulate in the U tube. If the class cannot solve the problem, then demonstrate as above, and then ask the class to explain why "blood" rises in the U tube. Now repeat the original question — "How does exercise help the heart circulate blood?"

III. Demonstrations to show pulse rate.

A. On sunny days, a small piece of mirror placed on the pressure point in the wrist, back of the thumb, will reflect pulse vibrations on the ceiling of the classroom for all to see.

B. A splint glued to a tack and placed over the same region will also show the pulse rate.

C. A home-made manometer attached to a short stemmed thistle tube by means of rubber tubing shows pulse rate nicely.

1. Bend glass tubing to form a 4″ to 5″ U tube. Fire polish both ends. Fill with red ink and attach to the thistle tube by means of rubber tubing. See diagram B.

2. Hold the thistle tube over the pressure point in the neck. The fluid in the U tube pulsates. If a white card is held behind the manometer, it is visible to the entire class. If the U tube is inserted in a slide projector an image of the pulsating fluid is projected onto a screen. The effects of various activities on pulse rate can be shown to the entire class. A pupil was asked to do a long division problem and the effect on his pulse rate was noted.

IV. Blood typing of a group of students.

A. Have each student prepare a 3 x 5 slip of paper by ruling it in half and marking one side Anti-Serum A and the other side Anti-Serum B.

B. Have the pupils place a clean slide on

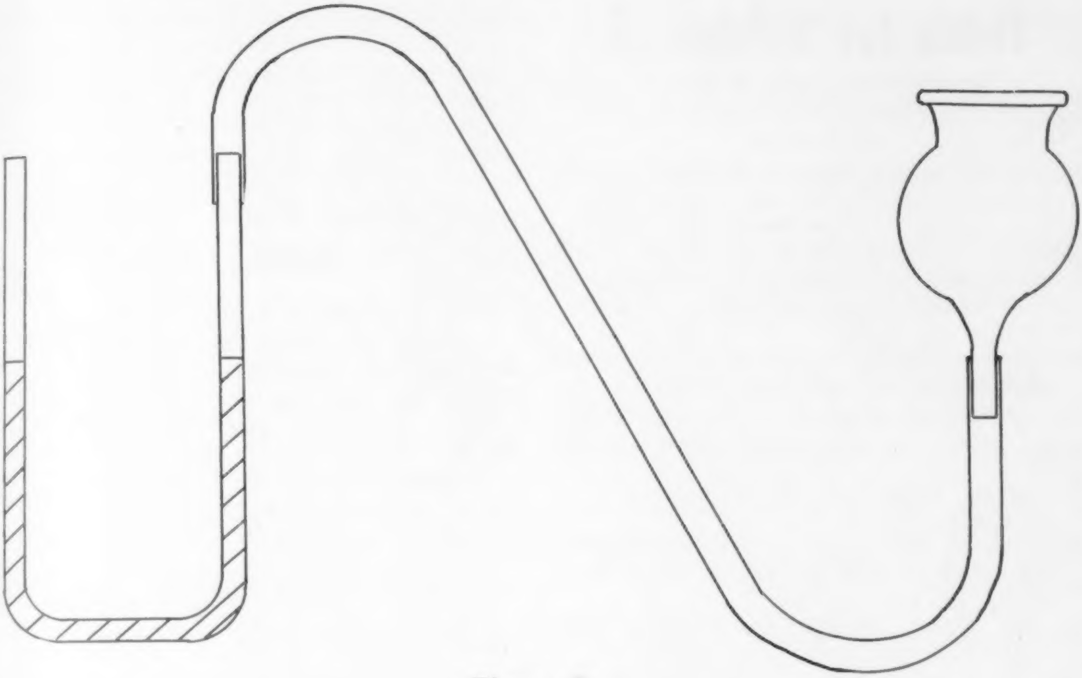


Diagram B

this paper. (The slide doesn't have to be marked with a glass marking pencil—easier to clean).

C. A flat toothpick is distributed to each participating pupil.

D. A student aid adds a drop of Anti-Serum A and of Anti-Serum B to each slide. (Serums are available from most supply houses).

E. Another student aid circulates about the room sterilizing fingers with a cotton swab moistened with 70% alcohol.

F. The teacher using a Hagedorn needle or disposable sterilized needles (now available from supply houses) pricks the sterilized fingers of pupils.

G. The pupils using one end of the toothpick stir a drop of blood into Anti-Serum A; using the other end of the toothpick a second drop of blood is stirred into Anti-Serum B.

H. The students rock the slide from side to side several times.

I. A reading should be taken within 2 minutes.

J. Using a chart (supplied with the serums) the pupils determine their blood type.

K. Have the pupils record their blood type, religion, race, etc. on the 3x5 slip of paper.

L. A committee of students can use this information to determine the distribution of blood types. The resulting class discussion leads to favorable intergroup reactions and relationships.

## Anti-Tumor Drug

The isolation and concentration of an anti-tumor drug, active against some forms of cancer in animals, was reported by Dr. K. V. Rao of the John L. Smith Memorial for Cancer Research, Maywood, N. J. The drug was designated E-73 and belongs to the same chemical family as actidone, an antibiotic substance which is made by the same mold-like micro-organisms which produces streptomycin. Actidone has some anti-cancer activity. The E-73 compound, Dr. Rao reported, is much more active than actidone, but it is also much more toxic. Thus, though it has shown suppressive activity against animal tumors, it is expected to prove too toxic to be useful in human patients. The discovery may, however, provide clues toward an understanding of the nature of the anti-tumor activity, he said.

# Index for Volume 21

Compiled by John D. Woolever
Riverview High School, Sarasota, Florida

## AUTHORS

## TITLES

## BOOK REVIEWS

*Biology, the Science of Life*, A. E. Lee, October, p. 244.

*British Mammals*, M. Burton, October, p. 247.

*Cellular Mechanisms in Differentiation and Growth*, D. Rudnick, May, p. 190.

*Communication, Organization and Science*, Jerome Rothstein, January, p. 27.

*Comparative Morphology of Vascular Plants*, A. S. Foster and E. M. Gifford, Jr., October, p. 145.

*Cortisone Therapy*, J. G. Glyn, October, p. 248.

*Crime and Insanity*, Richard W. Nice, November, p. 316.

*Dairy Microbiology*, E. M. Foster, et al., October, p. 247.

*Deafness, Mutism and Mental Deficiency in Children*, Louis Minski, May, p. 191.

*Developmental Cytology*, Dorothea Rudnick, October, p. 247.

*Development and Structure of the Frog, a Photographic Study*, A. E. Lee, E. R. Savage and W. L. Evans, October, p. 246.

*Dictionary of Poisons*, Ibert and Eleanor Mellan, April, p. 125.

*Dinosaurs, Predator and Prey*, Rainer Zangerl, May, p. 191.

*Discovering the Real Self*, E. F. McDaniel, October, p. 248.

*Dissection Guides*, H. G. Q. Rowett, January, p. 9.

*Education and Freedom*, H. G. Rickover, October, p. 245.

*Eels, a Biological Study*, Leon Burtin, May, p. 191.

*Elements of Ecology*, Geo. L. Clarke, April, p. 125.

*Elements of the Universe*, G. T. Seaborg and E. G. Evans, October, p. 246.

*Epilepsy*, L. Fairfield, May, p. 190.

*Epilepsy*, Manfred Sakel, November, p. 317.

*Experimental Psychology*, B. A. Farrell, February, p. 59.

*Fellowships in the Arts and Sciences*, V. B. Potter, October, p. 145.

*Food and You*, E. S. Nasset, October, p. 248.

*Fruit Key and Twig Key*, William M. Harlow, November, p. 316.

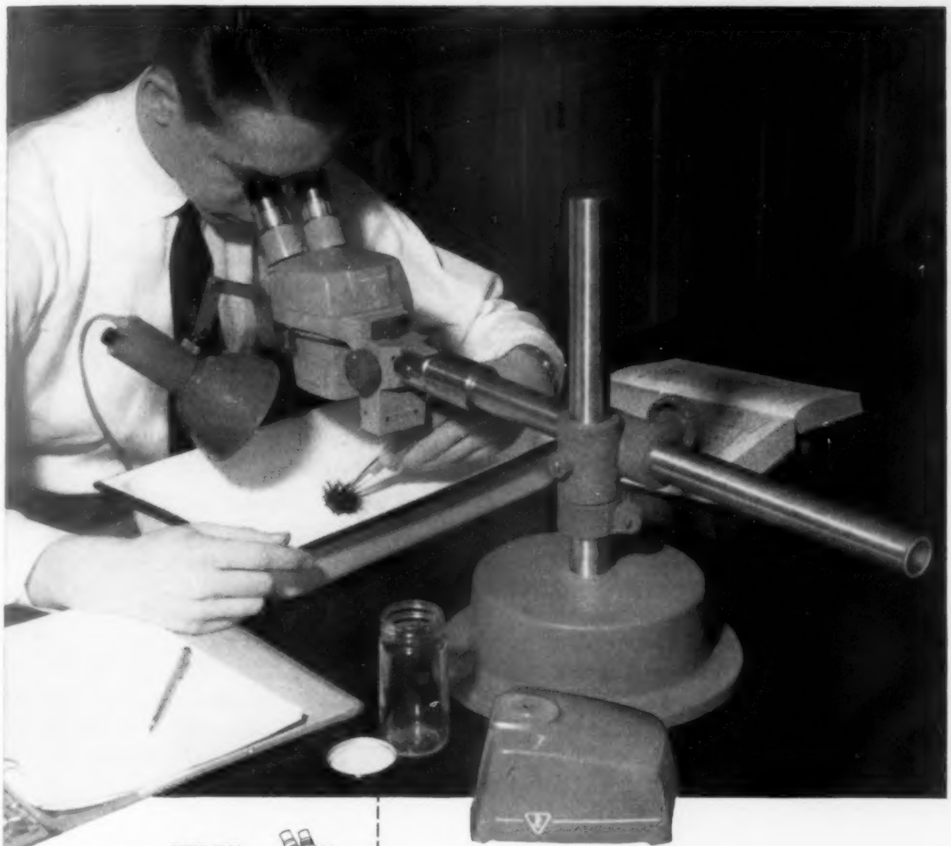
*General and Applied Entomology*, V. A. Little, January, p. 27.

*Genetics Is Easy*, Philip Goldstein, March, p. 101.

*Group Psychoanalysis*, B. B. Wassell, October, p. 248.

*Handbook of Toxicology*, Vol. IV, *Tranquilizers*, M. Gordon and R. F. J. McCandless, October, p. 244.

Vol. V, *Fungicides*, Barbara L. Tuma and L. C. Lee, November, p. 316.
Vol. III, *Insecticides*, William O. Negherbon, November, p. 316.
*History of Biology*, F. S. Bodenheimer, October, p. 245.
*Hypnotic Suggestions*, S. J. Van Pelt, May, p. 190.
*Insight*, B. J. F. Lonergan, October, p. 248.
*Introduction to Human Anatomy*, C. C. Francis, October, p. 247.
*Isotopic Tracers*, G. E. Francis, W. Mulligan and A. Wormall, January, p. 11.
*Juvenile Delinquency*, Joseph S. Roucek, November, p. 316.
*Laboratory Directions in General Zoology*, M. J. Guthrie and J. M. Anderson, October, p. 247.
*Laboratory Outline for General Zoology*, George Edwin Potter, February, p. 44.
*Learning and Instinct in Animals*, W. H. Thorpe, April, p. 134.
*Lives of Game Animals*, Vol. IV, Part II, E. T. Seton, May, p. 189.
*Living Earth*, Peter Farb, November, p. 316.
*Mammals of the Great Lakes Region*, William H. Burt, May, p. 191.
*Man's World of Sound*, J. Pierce and E. David, October, p. 246.
*Manual of Scientific Russian*, Thomas Magner, April, p. 131.
*Manual of Southern Forestry*, Howard E. Weaver and D. A. Anderson, January, p. 23.
*Microbiology and Epidemiology*, LaVerne Ruth Thompson, March, p. 100.
*Microsomal Particles and Protein Synthesis*, Richard B. Roberts, April, p. 134.
*Natural History of Birds: A Guide to Ornithology*, Leonard W. Wing, March, p. 97.
*Notes on Atomic Energy for Medical Officers*, The Royal Naval Medical School, May, p. 189.
*Our Nuclear Adventure*, D. G. Arnott, February, p. 56.
*Physiology of Muscular Activity*, P. V. Karpovich, October, p. 248.
*Plant Ecology*, William Leach, May, p. 189.
*Plant Propagation, Principles and Practices*, H. T. Hartmann and D. E. Kester, October, p. 248.
*Poison on the Land*, J. Wentworth Day, April, p. 133.
*Police Drugs*, Jean Rolin, May, p. 191.
*Preface to Empathy*, David A. Stewart, April, p. 134.
*Prehistoric Man*, A. Leroi-Gourhan, May, p. 190.
*Principles of Field Biology and Ecology*, A. H. Benton and W. E. Werner Jr., May, p. 190.
*Principles of Immunology*, J. E. Cushing and D. H. Campbell, October, p. 247.
*Purchase Guide for Programs in Science, Mathematics, Modern Foreign Languages*, Council of Chief State School Officers, October, p. 245.
*Reason and Chance in Scientific Discovery*, R. Taton, October, p. 247.



# New Flower Model
# of colored vinyl plastic

This new model of shatterproof vinyl plastic is completely three-dimensional and is sufficiently enlarged to be effective before large classes. The flower is 17 inches high and 24 inches in width. Turtox Catalog Number TM-393. Price, $75.00.

Turtox Models include enlarged and dissectible models of human anatomy, embryology, biology, botany and zoology. All are constructed of vinyl plastic or of latex, and all are shatterproof and unbreakable under laboratory conditions.

For descriptions and pictures of all of the Turtox Models examine pages 265 through 290 in the new Turtox Biology Catalog No. 61.

FOR THE BIOLOGICAL SCIENCES
TURTOX PRODUCTS

GENERAL BIOLOGICAL SUPPLY HOUSE
Incorporated
8200 South Hoyne Avenue, Chicago 20, Illinois

*The Sign of the Turtox Pledges Absolute Satisfaction*